Multiattribute Utility Theory,

Intertemporal Utility and Correlation Aversion

by

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ABSTRACT. Convenient assumptions about qualitative properties of the intertemporal utility function have generated counter-intuitive implications for the relationship between atemporal risk aversion and the intertemporal elasticity of substitution. If the intertemporal utility function is additively separable then the latter two concepts are the inverse of each other. We review a simple theoretical specification with a long lineage in the literature on multi-attribute utility, and demonstrate the critical role of a concept known as intertemporal correlation aversion. This concept is the intertemporal analogue of a more general concept applied to two attributes of utility, but where the attributes just happen to be the time-dating of the good. In the context of intertemporal utility functions, the concept provides an intuitive explanation of possible differences between (the inverse of) atemporal risk aversion and the intertemporal elasticity of substitution. We use this theoretical structure to guide the design of a series of experiments that allow us to identify and estimate intertemporal correlation aversion. Our results show that subjects are correlation averse over lotteries with intertemporal income profiles, and that the convenient additive specification of the intertemporal utility function is not an appropriate representation of preferences over time.

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Convenient assumptions about qualitative properties of the intertemporal utility function have generated counter-intuitive implications for the relationship between atemporal risk aversion and the intertemporal elasticity of substitution. If the intertemporal utility function is additively separable then these two concepts are the inverse of each other. To explain the apparent lack of substitutability of consumption between periods one is led to assume a low intertemporal elasticity of substitution, implying absurdly high levels of atemporal risk aversion. This is no technical side issue: untangling it is central to the general understanding of savings behavior (e.g., Hall [1988]), the analysis of insurance decisions by poor households in developing countries (e.g., Townsend [1994]), and the behavior of asset prices over time (e.g., Hansen and Singleton [1983]).

Our contribution is to demonstrate that weakly separable, non-additive representations of preferences, built from a well-known theoretical foundation of intertemporal utility, can be estimated from controlled choices in a field experiment with adult Danes. Moreover, we show how one can incorporate different models of risk preferences that have empirical support from the modern experimental literature. Our approach is flexible in this regard, allowing one to examine popular modern alternatives to EUT, such as Rank Dependent Utility (RDU) for example. We can also easily examine popular behavioral alternatives to exponential discounting.

The core concept we investigate is known as *correlation aversion*. It arises from theoretical deviations from additively separable intertemporal utility functions, such as the deviations we employ here. Define the lottery α as a 50:50 mixture of $\{x, Y\}$ and $\{X, y\}$, and the lottery θ as a 50:50 mixture of $\{x, y\}$ and $\{X, Y\}$, where $X>x$ and $Y>y$. So α is a 50:50 mixture of both bad and good outcomes in time t and $t+\tau$; and θ is a 50:50 mixture of only bad outcomes or only good outcomes in the two time periods. These lotteries α and θ are defined over all possible "good" and "bad" outcomes. If the individual is indifferent between α and θ we say that he is neutral to intertemporally correlated payoffs in the two time periods. If the individual prefers α to θ we say that he is averse to intertemporally correlated payoffs: it is better to have a given chance of being lucky in one of the two periods than to have the same chance of being very unlucky or very lucky in both periods. The correlation averse individual prefers to have non-extreme payoffs *across* periods, just as the risk averse individual prefers to have non-extreme payoffs *within* periods. One can also view the correlation averse individual as preferring to avoid correlation-increasing transformations of payoffs in different periods.

Keeney [1972][1972][1973] developed the essential technical concepts of conditional utility functions and conditional risk aversion for two or more attributes. Richard [1975] formally stated the main results in terms of multivariate risk aversion, to be contrasted with univariate risk aversion. Epstein and Tanny [1980] sharply defined the specific concept of correlation aversion.[1] Since we interpret the two attributes as referring to different time periods, we refer to intertemporal risk aversion or intertemporal correlation aversion.[2] There are direct parallels in the older literature on multi-attribute utility (Fishburn [1965], Keeney [1971][1972], Pollack [1967] and Harvey [1993]). There are also parallels in the older literature on multivariate risk aversion (Kihlstrom and Mirman [1974], Rothblum [1975], Duncan [1977] and Karni [1979]), as demonstrated by Eeckhoudt, Rey and Schlesinger [2007] and Dorfleitner and Krapp [2007]. And the concept of correlation aversion provides insight into important properties of univariate risk aversion, such as properness, prudence and temperance (Denuit, Eeckhoudt and Rey [2010]).

In section 1 we review a simple theoretical specification, which has a long lineage in the literature on multi-attribute utility, and demonstrate the critical role of intertemporal risk aversion or intertemporal correlation aversion. In section 2 we use this theoretical structure to guide the design of a series of experiments that allows us to identify the core parameters of the latent structural models. We also discuss our specific experiments, conducted throughout Denmark using a representative sample of the adult Danish population. In section 3 we review econometric models used to estimate the core

[1] Keeney and Raiffa [1976; Chapter 5] remains a superb exposition of the basic ideas and theorems.

[2] Everything we say about intertemporal risk aversion or intertemporal correlation aversion applies symmetrically to behavior that exhibits intertemporal risk loving or intertemporal correlation loving.

parameters of the models.

Section 4 contains results, and *provide the first estimates of the extent of intertemporal correlation aversion.* Our results show that subjects are indeed correlation averse over lotteries with intertemporal income profiles, and that the convenient additive specification of the intertemporal utility function is not an appropriate representation of preferences over time. We also show that *intertemporal correlation aversion contributes significantly to the overall risk premium that characterizes risky intertemporal profiles.* Finally, we demonstrate the flexibility of our approach, by considering the "modular" effect on estimates of correlation aversion of allowing for popular specifications of non-exponential discounting and non-EUT risk preferences. Section 5 concludes.

Additional details are related to online appendices. Appendix A documents the experimental instructions; appendix B documents the experimental design and procedures; and appendix C provides detailed estimates allowing for observable heterogeneity in demographics and experimental procedures.

1. Theory

We consider first an intertemporal decision model with weakly separable preferences under EUT. The intertemporal utility function at time t=0 is written as:

$$U(X_1, X_2,..., X_n) = E[\ \varphi\ (\ \textstyle\sum_{t=1}^{n} (1/(1+\delta)^t\ )\ u(x_t)\ )\ ] \tag{1}$$

where $x_t \in X_t$, $u(x_t)$ is the atemporal utility of money at time t, and δ is the exponential discount rate. For now, let φ be an identity function; we return to it momentarily. The decision tasks in our experiments provide lotteries with payments at two different points in time, where the time horizon between sooner and later payments varied between 2 weeks and 12 months. We can simplify the model in (1) and consider decisions that involve payments at two different points in time. Assuming u(0)=0, the intertemporal utility function is specified as:

$$U(X_t, X_{t+\tau}) = E[\ \varphi\ (\ D_t\ u(x_t) + D_{t+\tau}\ u(x_{t+\tau})\ )\ ] \tag{2}$$

where $D_t = 1/(1+\delta)^t$ is the discounting function with a constant discount rate δ.

Let the atemporal utility function be the constant relative risk aversion (CRRA) specification:

$$u(x_t) = x_t^{\ 1-r}/(1-r) \tag{3}$$

for $r \neq 1$, where r is the CRRA coefficient, assumed for simplicity to be the same for periods t and $t+\tau$. With this functional form, $r=0$ denotes risk neutral behavior, $r>0$ denotes risk aversion, and $r<0$ denotes risk seeking behavior, all defined over atemporal tradeoffs in t or $t+\tau$.

Given the popularity of the CRRA function in the microeconomic and macroeconomic literature, it is natural to consider this alternative structural specification of the intertemporal utility function φ:

$$U(X_t, X_{t+\tau}) = E\,[\,(\,D_t\, u(x_t) + D_{t+\tau}\, u(x_{t+\tau})\,)^{(1-\eta)}/(1-\eta)\,] = E\,[\,\xi(x_t, x_{t+\tau})^{\ (1-\eta)}/(1-\eta)\,] \tag{4}$$

where η is the intertemporal relative risk aversion parameter ($\eta \neq 1$), and the expression for the weighted sum of atemporal utility flows, $\xi(x_t, x_{t+\tau})$, is useful below.[3] The intertemporal utility function is separable but not additive when $\eta \neq 0$, and collapses to $E[\,\xi(x_t, x_{t+\tau})\,]$ when there is intertemporal risk neutrality at $\eta=0$.[4] We estimate the structural parameters in this model and discuss results in section 4.

If the intertemporal utility function in (4) is additively separable, then the inverse of the intertemporal elasticity of substitution is equal to the coefficient of atemporal risk aversion. This assumption is one of convenience and is popular in models of intertemporal choice. The linear

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[3] See Epstein [1983], Epstein and Zin [1989], Farmer [1990], Weil [1990], Bommier [2006][2007][2013], Bommier and Le Grand [2014], Bommier and Rochet [2006] and Epstein, Fahri and Strzalecki [2014] for discussion of alternative specifications of the intertemporal utility function and implications for intertemporal risk aversion. The specification in (4) can generate negative discount rates unless we assume that $r<1$ and $\eta<1$ to ensure that $\delta>0$. This assumption is empirically innocuous, as we demonstrate later with estimated parameter values. Andersen, Harrison, Lau and Rutström [2008a] add background consumption ω to a CRRA specification of atemporal utility and apply the function $u(x_t) = (\omega+x_t)^{1-r}/(1-r)$, where $u(\omega)>0$. They show that this function is well behaved when the intertemporal utility function is additively separable, in the sense that the addition of background consumption is a sufficient condition to avoid negative discount rates. However, adding background consumption to experimental income is problematic in the estimation of the non-additive function in (4) because one has to specify the atemporal utility of background consumption at every point in time and not only when the sooner and later payments are made.

[4] See Deaton and Muellbauer [1980; p.137] for a discussion of strong separability and additive preferences. Tsetlin and Winkler [2009] provide a rich, general characterization of the class of utility functions that allow correlation aversion, in the form of mixtures of exponential functions.

specification of intertemporal utility is then equal to a weighted sum of atemporal utility flows, where the weights are determined by the discount rate.

Following the exposition of Bommier [2007], we can define a number of important concepts using this structure. The marginal rate of substitution between money in periods t and t+τ can be defined as

$$\mathrm{MRS}_{t,\, t+\tau} = (\partial U/\partial x_t)/(\partial U/\partial x_{t+\tau}) \tag{5}$$

The coefficient of relative risk aversion in period t can be defined by

$$\mathrm{RRA}_{t} = -x_t\, [\partial^2 U/(\partial x_t)^2] \,/\, (\partial U/\partial x_t) \tag{6}$$

The (direct) elasticity of substitution between money in periods t and t+τ is

$$\sigma_{t,t+\tau} = \{1/x_t\, (\partial U/\partial x_t) + 1/x_{t+\tau}\, (\partial U/\partial x_{t+\tau})\} \,/\, \{a + b + c\} \tag{7}$$

where $a = -[\partial^2 U/(\partial x_t)^2] \,/\, (\partial U/\partial x_t)^2$, $b = 2\, [\partial^2 U/(\partial x_t\, \partial x_{t+\tau})] \,/\, [(\partial U/\partial x_t)(\partial U/\partial x_{t+\tau})]$, and $c = -[\partial^2 U/(\partial x_{t+\tau})^2] \,/\, (\partial U/\partial x_{t+\tau})^2$. Finally, a coefficient of correlation aversion with respect to money flows in periods t and t+τ can be defined as

$$\varrho_{t,\, t+\tau} = -2\, [\partial^2 U/(\partial x_t\, \partial x_{t+\tau})] \,/\, [\partial U/\partial x_t + \partial U/\partial x_{t+\tau}] \tag{8}$$

Clearly $\varrho_{t,\, t+\tau} \geq 0$ if $\partial^2 U/\partial x_t\, \partial x_{t+\tau} \leq 0$, since $\partial U/\partial x_t \geq 0$ and $\partial U/\partial x_{t+\tau} \geq 0$, directly connecting this coefficient to the definition of correlation aversion under EUT proposed by Richard [1975].[5] The coefficient of correlation aversion is just one tractable way to measure the underlying concept of intertemporal risk aversion or correlation aversion, just as coefficients of absolute or relative risk aversion are just tractable ways to measure the concept of atemporal risk aversion.

With these concepts defined, there is a remarkable relationship between them noted by Bommier [2007; Proposition 1]:

$$1/\sigma_{t,\, t+\tau}\, (1+\mathrm{MRS}_{t,\, t+\tau}\, x_t/x_{t+\tau}) = (\mathrm{RRA}_{t} + x_t/x_{t+\tau}\, \mathrm{MRS}_{t,\, t+\tau}\, \mathrm{RRA}_{t+\tau}) - \varrho_{t,\, t+\tau}\, x_t\, (1+\mathrm{MRS}_{t,\, t+\tau}) \tag{9}$$

[5] The relations between correlation aversion, atemporal risk aversion and the intertemporal elasticity of substitution are not limited to EUT. Bommier [2005; §5] provides a general graphical interpretation that does not rely on EUT, and we consider RDU risk preferences later.

From (9) we see formally that correlation aversion breaks the nexus between the intertemporal elasticity of substitution and atemporal relative risk aversion.

Given the parametric structure we have assumed, we can further state the marginal rate of substitution between money in periods t and t+τ using (5) as

$$MRS_{t,\, t+\tau} = D_t\, x_t^{-r} / (D_{t+\tau}\, x_{t+\tau}^{-r}), \tag{5$'$}$$

the relative risk aversion in period t using (6) as

$$RRA_{\,t} = (\, \eta/[\, \xi(x_t, x_{t+\tau})\,]\,)\, D_t\, x_t^{\,1-r} + r, \tag{6$'$}$$

the (direct) elasticity of substitution between money in periods t and t+τ using (7) as

$$\sigma_{\,t,\, t+\tau} = 1/r, \tag{7$'$}$$

and finally the coefficient of correlation aversion with respect to money flows in periods t and t+τ using (8) as

$$\varrho_{\,t,\, t+\tau} = \{(\, 2\eta/[\, \xi(x_t, x_{t+\tau})\,]\,)\, D_{t+\tau}\, x_{t+\tau}^{-r}\, D_t\, x_t^{-r}\} \;/\; \{D_{t+\tau}\, x_{t+\tau}^{-r} + D_t\, x_t^{-r}\}. \tag{8$'$}$$

Hence $\varrho_{\,t,\, t+\tau}$ is positive (negative) when η is positive (negative). The specific functional forms for these concepts will vary with the parametric assumption assumed, of course.

To elicit intertemporal risk aversion one would have to present subjects with choices over lotteries that have different income profiles over time.[6] Proper identification of intertemporal risk aversion (η) thus requires that one controls for atemporal risk aversion (r) and the individual discount rate (δ). All three parameters are intrinsically, conceptually connected as a matter of theory, unless one makes strong assumptions otherwise. Our experimental design and econometric logic follow from this theoretical point.

[6] Keeney [1977] illustrates this in a one-on-one, conversational elicitation with a decision-maker. These lottery comparisons are used to justify the use of a correlation-neutral multiattribute utility function, and not to elicit the degree of correlation aversion. Delquie and Luo [1997] show how one can *test for* the tractable correlation-neutral class of functions using only two indifference judgements, rather than the set of lottery comparisons that are needed to *estimate the extent of* multiattribute risk aversion.

2. Experiments

The experimental procedures we adopt are a simple extension of those employed by Andersen, Harrison, Lau and Rutström [2008a][2013][2014]. Appendix B (available online) reviews the basic procedures, and we focus here on the extensions.

One task elicited atemporal risk attitudes for lotteries payable today, as a vehicle for inferring the concavity of the atemporal utility function. Another task elicited time preferences over non-stochastic amounts of money payable at different times: in general, a smaller, sooner amount and a larger, later amount. In some cases the sooner amount was paid out today, and in some cases it was paid out in the future.[7]

A third task, new to this design, elicited intertemporal risk attitudes by asking subjects to make a series of choices over risky profiles of outcomes that are paid out at different points in time.[8] For example, lottery A might give the individual a 10% chance of receiving a larger amount L_t at time t *and*

[7] One maintained assumption is that subjects do not have access to perfect capital markets with which to arbitrage the investment opportunities offered by the experimenter. In that case one should consider the effect of censoring of responses in line with borrowing and savings interest rates that the subject has available outside the experiment, as in Coller and Williams [1999] and Harrison, Lau and Williams [2002]. Even when markets are perfect, understanding the quantitative importance of correlation aversion can be important for understanding life-cycle behavior (Bommier [2013]).

[8] Other experiments with real incentives have examined choices over time-delayed risk, but where the time delay is the same for all outcomes within a given lottery (Noussair and Wu [1996], Coble and Lusk [2010], Baucells and Heukamp [2010] and Abdellaoui, Diecidue and Öncüler [2011]). This is an important domain of choice to examine, but is not intended to address the issue of correlation aversion. The only previous experiments with real incentives that we know of that explicitly test for *atemporal* multiattribute risk aversion were due to von Winterfeldt [1980]. He considered lottery choices of 18 subjects defined over 36 consumption bundles of gallons of gasoline and pounds of ground beef. For example, the lottery α might be a 50% chance of {16 gallons of gas and 10 pounds of ground beef} and a 50% chance of {no gas and no beef}, and the lottery β defined as a 50% chance of {10 pounds of ground beef} and a 50% chance of {16 gallons of gas}. He used three different methods of eliciting preference: direct statement of preference, including the option of indifference; a rating normalized between 0 and 100; and cash-equivalents elicited using an incentive-compatible Becker, DeGroot and Marschak [1964] procedure with buying prices elicited from between $0 and $20. It appears that only the choices in the last elicitation procedure were played out for real, although the exposition is not completely clear (contrast the top of page 73 and the top of page 70). There were some response mode effects, of the kind now known as "preference reversals," and some violations of non-satiation. But the general conclusion is that "Multiattribute risk aversion showed very clearly for all except two subjects" (p. 80). He also concluded that "Multiattribute risk aversion appeared unrelated to [...] single attribute risk aversion" (p. 81). Pliskin, Shepard and Weinstein [1980] and Payne, Laughhunn and Crum [1984] report experiments with *hypothetical* incentives that test for multiattribute risk neutrality, and respectively report results that support and reject that characterization.

a smaller amount $S_{t+\tau}$ at time t+τ, $(L_t, S_{t+\tau})$ and a 90% chance of receiving the smaller amount S_t at time t *and* the larger amount $L_{t+\tau}$ at time t+τ, $(S_t, L_{t+\tau})$. Lottery B might give the individual a 10% chance of receiving L_t *and* $L_{t+\tau}$ and a 90% chance of receiving S_t *and* $S_{t+\tau}$. The subject picks A or B. We gave subjects 40 choices of this type, in four sets of 10 choices with prizes $S_t=S_{t+\tau}$ and $L_t=L_{t+\tau}$ in each set. Each set of 10 choices offered prizes with probability $p(L_t, S_{t+\tau})=p(L_t, L_{t+\tau})$ starting at 0.1 and increasing by 0.1 until the last choice is between two degenerate lotteries. In this example, the last choice is a choice between receiving lottery A that pays $(L_t, S_{t+\tau})$ and lottery B that pays $(L_t, L_{t+\tau})$: lottery B dominates lottery A and is a test of monotonic preferences.

We present each choice to the subject as a "pie chart" showing prizes and probabilities. We use the following four sets of larger (L) amounts and smaller (S) amounts: [A1: (3850, 100)], [A2: (2000, 250)], [A3: (2000, 75)] and [A4: (4500, 50)]. Subjects were randomly assigned to one of these four prize sets. Each subject is presented with choices over four time horizons between 2 weeks and 1 year in the discount rate tasks, and the same four time horizons were applied in the intertemporal risk aversion tasks. We also varied the time delay to the early payments on a between-subjects basis, and this treatment followed from the discount rate tasks. If there was no time delay to the early payment in the discount rate tasks, then the early payments in the intertemporal risk aversion tasks were paid out immediately, and similarly if the delay to the early payment option in the discount rate tasks was 1 month.

Between September 28 and October 22, 2009, we conducted experiments with 413 Danes. The sample was drawn to be representative of the adult population as of January 1, 2009, using sampling procedures that are virtually identical to those documented at length in Andersen, Harrison, Lau and Rutström [2008a][2013][2014].

3. Econometrics

We consider non-additive separable specifications of the intertemporal utility function and estimate the coefficient of intertemporal risk aversion. Equation (4) implies that the expected utility of Option A in the intertemporal risk aversion task is given by

$$PEU_A = p(L_t , S_{t+\tau})\times[\ \xi(L_t, S_{t+\tau})^{(1-\eta)}/(1-\eta)\ ] + p(S_t, L_{t+\tau})\times[\ \xi(S_t, L_{t+\tau})^{(1-\eta)}/(1-\eta)\ ] \quad (10)$$

and the expected utility of Option B is given by

$$PEU_B = p(L_t, L_{t+\tau})\times[\ \xi(L_t, L_{t+\tau})^{(1-\eta)}/(1-\eta)\ ] + p(S_t, S_{t+\tau})\times[\ \xi(S_t, S_{t+\tau})^{(1-\eta)}/(1-\eta)\ ] \quad (11)$$

where $p(L_t, L_{t+\tau})$ is the probability of receiving L_t in period t and $L_{t+\tau}$ in period $t+\tau$.[9] We can write out the likelihood function for the choices that the subjects made and jointly estimate the risk parameter r, the discount rate parameter δ, and the intertemporal risk parameter η. We employ the contextual error specification proposed by Wilcox [2011], and the latent index is specified by

$$\nabla PEU = ((PEU_B - PEU_A)\lambda)/\mu^{SDR} \quad (12)$$

where μ^{SDR} is a noise parameter for the ("stochastic discounting") intertemporal risk aversion choices. The normalizing term λ is defined as the maximum intertemporal utility over all prize profiles in this lottery pair $(L_t, L_{t+\tau})$ minus the minimum utility over all prize profiles in this lottery pair $(S_t, S_{t+\tau})$. The maximum intertemporal utility over all prize profiles in the lottery pair is $[D_t\ u(L_t) + D_{t+\tau}\ u(L_{t+\tau})]^{(1-\eta)}/(1-\eta)$, and the minimum intertemporal utility is $[D_t\ u(S_t) + D_{t+\tau}\ u(S_{t+\tau})]^{(1-\eta)}/(1-\eta)$.

The likelihood of the intertemporal risk aversion responses, conditional on the specification of intertemporal utility being true, depends on the estimates of r, δ, η, μ^{SDR}, μ^{RA} and μ^{DR}, given the observed choices, where μ^{RA} is a noise parameter for the atemporal risk aversion choices and μ^{DR} is a noise parameter for the discount rate choices. The conditional log-likelihood is

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[9] We assume here that the atemporal utility function is stable over time and is perceived *ex ante* to be stable over time. Direct evidence for the former proposition is provided by Andersen, Harrison, Lau and Rutström [2008b], who examine the temporal stability of risk attitudes in the Danish population. The second proposition is a more delicate matter: even if utility functions are stable over time, they may not be subjectively perceived to be, and that is what matters for us to assume that the same r that appears in (3) appears in (10) and (11).

$$\ln L\,(r, \delta, \eta, \mu^{RA}, \mu^{DR}, \mu^{SDR}; c, \mathbf{C}) = \textstyle\sum_i \left[(\ln \Lambda(\nabla PEU) \times \mathbf{I}(c_i=1)) + (\ln (1-\Lambda(\nabla PEU)) \times \mathbf{I}(c_i=-1)) \right] \quad (13)$$

where $c_i = 1(-1)$ denotes the choice of Option B (A) in intertemporal risk aversion task i, and **C** is a vector of individual characteristics.

The joint likelihood of the atemporal risk aversion, discount rate and intertemporal risk aversion responses can then be written as

$$\ln L\,(r, \delta, \eta, \mu^{RA}, \mu^{DR}, \mu^{SDR}; c, \mathbf{C}) = \ln L^{RA} + \ln L^{DR} + \ln L^{SDR} \quad (14)$$

where L^{RA} is the conditional log-likelihood of the atemporal risk aversion responses, L^{DR} is the conditional log-likelihood of the discount rate responses and L^{SDR} is defined by (13).

The nature of this joint likelihood function is matched by our experimental design. Ignoring the objective parameters of the tasks, the lottery choices over stochastic lotteries paid out today (RA) depend on r, η and μ^{RA}; the discounting tasks over non-stochastic outcomes paid out today or some time in the future (DR) depend on r, μ^{RA}, δ and μ^{DR}; and the discounting tasks over stochastic outcomes paid out today or some time in the future (SDR) depend on r, μ^{RA}, δ, μ^{DR}, η and μ^{SDR}. Putting the behavioral error terms aside, if we were to try to estimate r and δ using either the RA or the DR choices, we would be unable to identify both parameters. Similarly, if we were to try to estimate r, δ and η using only two of three tasks, we would face an identification problem. These identification problems are inherent to the theoretical definitions of the discount rate and correlation aversion, and demand an experimental design that combines multiple types of choices and an econometric approach that recognizes the complete structural model. The general principle is joint estimation of all structural parameters so that uncertainty about the parameters defining the utility function propagates in a "full information" sense into the uncertainty about the parameters defining the discount function and the intertemporal utility function. Intuitively, if the experimenter only has a vague notion of what u(.) is, because of poor estimates of r, then one simply cannot make precise inferences about δ or η. Similarly, poor estimates of δ, even if r is estimated relatively precisely, imply that one cannot make precise inferences about η.

Our inferential procedure about correlation aversion does not rely on the use of EUT, or the CRRA functional form. Nor does it rely on the use of the exponential discounting function. The method generalizes immediately to alternative multiattribute models of decision making under risk, such as those presented in Miyamota and Wakker [1996]. It also extends to specifications that use alternative discounting functions, as illustrated in §4.D.

4. Results

A. Basic Results

Table 1 reports maximum likelihood estimates of the specification with the CRRA atemporal utility function.[10] There is evidence of a concave atemporal utility function (r>0), with r estimated to be 0.35. The discount rate is estimated to be 11.4% on an annualized basis.[11] The main novelty here is evidence of intertemporal risk aversion, with η estimated to be 0.32 and statistically significantly different from 0. The implication is that there should be a difference between the inverse of RRA and the intertemporal elasticity of substitution IES (which is equal to 1/r), and this is confirmed by the implied estimates in Panel D of Table 1. The IES is estimated to be 2.85 with a standard error of 0.31, and exceeds the inverse of RRA by 0.65.[12] This difference between the IES and the inverse of RRA is statistically significant with a *p*-value less than 0.001.

We can derive the certainty equivalents for each lottery in Option A and Option B of the intertemporal risk aversion tasks using (4), and then evaluate the risk premia associated with different

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[10] Virtually identical results are obtained if one uses the Expo-Power atemporal utility function.

[11] The estimates of r and δ are different to those reported for the specification in Andersen, Harrison, Lau and Rutström [2008a] that sampled the same adult Danish population in 2003, but assumed intertemporal risk neutrality. In that case the point estimate of r = RRA was 0.74 and the discount rate δ was estimated to be 10.1% (Table III, p.601). If we impose the constraint η=0 in our analysis, the log-likelihood drops significantly from -26361.2 to -26568.5, with r estimated to be 0.55 and δ is equal to 7.7%.

[12] We evaluate RRA in the special case where $MRS_{t,t+\tau}(x_t/x_{t+\tau}) = 1$. In this case $RRA_t = RRA_{t+\tau} = \eta(1-r)/2 + r$.

prize sets.[13] Option A pays $(L_t, S_{t+\tau})$ with probability $p(L_t, S_{t+\tau})$ and $(S_t , L_{t+\tau})$ with probability $(1-p(L_t, S_{t+\tau}))$. The decision tasks are designed such that $S_t=S_{t+\tau}$ and $L_t=L_{t+\tau}$. If we assume, for simplicity, that the discount rate is equal to zero, then the present value of Option A is $L_t+S_{t+\tau}$ kroner. If we define the certainty equivalent as either $(L_t, S_{t+\tau})$ or $(S_t, L_{t+\tau})$ then the risk premium is equal to zero for the lotteries in Option A. However, if we define the certainty equivalent as the same certain amount to be paid out in both time periods, then the certainty equivalent is

$$CE_A = [(L_t^{(1-r)}+S_{t+\tau}^{(1-r)})/2]^{1/(1-r)} \tag{15}$$

where CE_A is paid out in period t *and* in period $t+\tau$. We can then define the risk premium of the lotteries in Option A as

$$RP_A = (L_t+S_{t+\tau}) - 2CE_A \tag{16}$$

The subject prefers smoothing consumption over time if the atemporal utility function is concave, which is just to say that the risk premium is positive when $r>0$. Using the estimates from Table 1, the estimated risk premium is 911 kroner for prize set A1, 288 kroner for prize set A2, 440 kroner for prize set A3, and 1,193 kroner for prize set A4.

If we allow the discount rate to be positive then the certainty equivalent for Option A is

$$CE_A = [((1-\eta)\ PEU_A)^{1/(1-\eta)}\ (1-r)\ /\ (D_t + D_{t+\tau})]^{1/(1-r)} \tag{15$'$}$$

where PEU_A is the expected utility of Option A given by (10). The risk premium is then derived as

$$RP_A = p(L_t, S_{t+\tau})\times\xi(L_t, S_{t+\tau}) + (1-p(L_t, S_{t+\tau}))\times\xi(S_t, L_{t+\tau}) - (D_t + D_{t+\tau})\times CE_A \tag{16$'$}$$

The estimated risk premium for prize set A1 varies between 855 kroner when $p(L_t, S_{t+\tau})=1$ and 868 kroner when $p(L_t, S_{t+\tau})=0.1$. The estimated risk premium for A2 is 271 and 274 kroner for $p(L_t, S_{t+\tau})$ equal to 1 and 0.1, respectively. Similarly, the risk premium interval is [413; 419] for A3 and [1,119;

[13] The *matrix* of risk premia in the multiattribute case is characterized by Duncan [1977] and Karni [1979]. Kihlstrom and Mirman [1974; §2.2] derived a "directional risk premium" which takes on as many values as there are possible "directions," and so is also multi-valued. But they pointed out that their measure allowed unique comparisons of utility functions representing the same ordinal preferences. The general point is that one cannot define risk premia as simply as when only considering the single-attribute case of univariate risk aversion.

1,139] for A4. Hence, the estimated risk premium for Option A falls slightly when we consider positive discount rates.

The lotteries in Option B pay $(L_t, L_{t+\tau})$ with probability $p(L_t, L_{t+\tau})$ and $(S_t, S_{t+\tau})$ with probability $(1-p(L_t, L_{t+\tau}))$. The certainty equivalent of Option B is

$$CE_B = [p(L_t, L_{t+\tau}) \times L_t^{(1-r)(1-\eta)} + (1-p(L_t, L_{t+\tau})) \times S_t^{(1-r)(1-\eta)}]^{1/(1-r)(1-\eta)} \tag{15''}$$

where CE_B is again a certain amount that is paid out in both period t *and* period t+τ. This definition of certainty equivalence implies that CE_B is independent of the discount rate and is equal to L_t if $p(L_t, L_{t+\tau})=1$ and equal to S_t if $p(L_t, L_{t+\tau})=0$. The risk premium is then

$$RP_B = p(L_t, L_{t+\tau}) \times L_t + (1-p(L_t, L_{t+\tau})) \times S_t - CE_B \,, \tag{16''}$$

which is equal to 0 if $p(L_t, L_{t+\tau})$ is equal to 0 or 1.

Figure 1 displays the estimated risk premium as a function of $p(L_t, L_{t+\tau})$ for each of the four prize sets in Option B of the intertemporal risk aversion task. The solid line is based on the estimated parameter values for r and η in Table 1, and the dashed line is based on a constrained model in which we assume that η is equal to 0 and r is kept constant and equal to 0.35. Hence the risk premium when η=0, and the decision maker is assumed to be correlation neutral (CN), derives entirely from the atemporal risk aversion r of the decision maker. When η and r are positive, and the decision maker is correlation averse (CA) as well as being atemporally risk averse, the risk premium derives from both types of risk aversion. The results show that *intertemporal risk aversion accounts for a substantial amount of the estimated risk premium*. For example, the upper left panel shows that the risk premium for prize set B1 is equal to 1,522 kroner in the unconstrained model when $p(L_t, L_{t+\tau})=0.5$ and is equal to 910 kroner when the intertemporal risk aversion parameter η is constrained to be 0, so the difference of 612 kroner is due to correlation aversion.

B. Observable Characteristics

It is a simple matter to extend the econometric model to allow structural parameters to depend on observed demographics and experimental treatments. Appendix C (available online) does this, and provides detailed estimates. The results imply considerable heterogeneity. Young subjects have lower estimated atemporal risk attitudes (r) than older subjects, with an estimated marginal effect of -0.58 that is statistically significant with a *p*-value of 0.024. We find similar marginal effects for students and subjects with kids, and cannot reject the hypothesis that subjects with these characteristics have linear atemporal utility functions. The results also point to a negative correlation between relative risk aversion and income: subjects with low income are significantly more risk averse than those with middle or high income, and subjects with high income are significantly less risk averse than those with middle income. It is noteworthy that there is *no significant gender effect on atemporal risk aversion*: women exhibit greater risk aversion (+0.14) than men, but the 95% confidence interval on this estimate spans zero, and the *p*-value is only 0.24.

Despite the considerable variation in atemporal risk attitudes, we find that only one of the demographic characteristics is significantly correlated with individual discount rates (δ). Young subjects have higher discount rates than older subjects, and the marginal effect of 8.8% is significant with a *p*-value of 0.024.[14]

There is a significant age effect on intertemporal risk attitudes as measured by η. Young subjects are significantly more intertemporally risk averse than those above 40 years of age; the marginal effect is 0.25 with a standard error of 0.09 and a *p*-value of 0.006. We also find a gender effect, with women being more risk averse over lotteries with intertemporal payment profiles than men. The

[14] One task characteristic is significantly correlated with discount rates: information on interest rates in the discounting choices has a negative effect on inferred discount rates. The estimated effect is -4.3% with a standard error of 2.3% and a *p*-value of 0.064.

estimated η is 0.25 larger for women, and this estimate has a *p*-value of only 0.006.[15]

Table C2 shows the implied estimates of relative risk aversion and the intertemporal elasticity of substitution. Younger subjects, students, and those with kids have linear atemporal utility functions and the IES coefficient is effectively infinite for these subjects. We also infer significantly negative marginal effects on the RRA coefficient for these three types of subjects. The marginal effect on RRA for young subjects is -0.46 with a *p*-value of 0.079, it is -0.52 for subjects with kids (*p*-value of 0.066), and is -0.58 for students (*p*-value of 0.063). Finally, the results point to a significant positive marginal effect on RRA for subjects with low income and a significant negative marginal effect for subjects with high income. Hence, there is evidence that RRA declines with income, but we find no significant effect of income on the IES coefficient.

We also evaluate the *total effects* of several of the demographic characteristics on the estimated RRA and IES, by estimating marginal effects without controls for other characteristics. We calculate total effects since many demographic characteristics co-vary in the population and therefore also in our sample. We find that women are more risk averse than men with an estimated RRA of 0.45 for women and 0.33 for men. This difference in RRA between men and women is statistically significant with a *p*-value of 0.026. However, we cannot reject the hypothesis that men and women have identical IES coefficients; the difference of 0.37 has a *p*-value of 0.740. There is an age effect on the two RRA and IES coefficients. The older age group has a higher RRA and lower IES than younger subjects, where the difference in RRA is significant with a *p*-value of 0.064 and the difference in IES has a *p*-value of 0.102. We cannot reject the hypothesis that the coefficients of RRA and IES are similar across income groups and education levels.

[15] We find a significant effect of sex on relative risk aversion and discount rates when the intertemporal utility function is mis-specified to be additively separable: women appear to be significantly more risk averse and patient in monetary terms than men.

C. The Coefficient of Correlation Aversion

Figure 2 displays the predicted distribution of the coefficient of correlation aversion (CCA), evaluated using (8′) and the four prize sets in the intertemporal risk aversion tasks. The upper left panel shows predicted CCA values for the income profile with high sooner payments and low later payments. The predicted mean is 0.10 (÷ 1000), with a standard deviation of 0.07 (÷ 1000). There is clear evidence of correlation aversion in general, although roughly 5% of the sample exhibit correlation neutrality or correlation loving preferences. The lower left panel displays the predicted distribution for the income profile with low sooner payments and high later payments. If the individual discount rate is equal to 0 then the predicted values of CCA in the upper and lower left panels would be the same. The predicted mean of the individual discount rate for the sample is 0.10 with a standard deviation of 0.08, and we therefore see small differences between the estimated means and standard deviations across the two income profiles in the upper and lower left panels. The upper and lower right panels show the predicted distributions for the income profiles with two high payments and two low payments respectively. The general pattern is the same as before, although the estimated means and standard deviations are lower (higher) for the income profile with two high (low) payments. Thus we observe correlation aversion in general across the four income profiles in the intertemporal risk aversion tasks.[16]

[16] We can also consider a more flexible specification of the intertemporal utility function and replace the η-parameter in (4) with a two-parameter version of the cumulative gamma distribution. There are very few *a priori* restrictions on the shape of the gamma distribution other than those of a cumulative density function. The estimated coefficients of r and δ are then different from before: the estimated IES is equal to 1.08 and the discount rate is estimated to be 1.3% on an annualized basis. However, we find that the estimated CCA is higher when the CRRA specification of (4) is replaced by the gamma distribution. We evaluate the CCA using the four prize sets in the intertemporal risk aversion tasks, as before, and find that CCA is 37.5 (÷ 1000) for the income profile with low sooner payments and low later payments, and 2.1 (÷ 1000) for the income profile with high sooner payments and high later payments. The estimated CCA are significantly different from 0, and we continue to observe correlation aversion in general when the gamma function is used.

D. Non-Exponential Discounting

One of the advantages of our approach is that one can consider "modular" changes in the modeling of time preferences and risk preferences. This is desirable given the popularity of alternatives in the modern behavioral and experimental literature, surveyed by Starmer [2007] and Frederick, Loewenstein and O'Donoghue [2002].

Our objective here is to demonstrate that the concept of intertemporal correlation aversion does not depend on the use of the exponential discounting model. To illustrate the generality of the results, we consider the effect of using two popular alternative discounting models.[17] The exponential discounting model may be viewed as assuming a *constant variable utility cost* per time period of delay. The two alternatives we consider are the Quasi-Hyperbolic specification that allows for a *fixed utility cost* as well as a *constant* variable utility cost, and the Weibull specification that allows for a *non-constant variable* utility cost.

The discount factor for the Quasi-Hyperbolic (QH) specification is defined as

$$D^{QH}(t) = 1 \qquad \text{if } t = 0 \tag{17a}$$
$$D^{QH}(t) = \beta/(1+\delta)^t \qquad \text{if } t > 0 \tag{17b}$$

where $\beta<1$ implies quasi-hyperbolic discounting and $\beta=1$ is exponential discounting. The defining characteristic of the QH specification is that the discount factor has a jump discontinuity at $t=0$, and is thereafter the same as the exponential specification. The discount rate for the QH specification is the value of d^{QH} that solves $D^{QH} = 1/(1+d^{QH})$, so it is

$$d^{QH}(t) = 1/\ [\ \beta/(1+\delta)^t\ ]^{(1/t)} - 1 \tag{18}$$

for $t>0$. Thus for $\beta<1$ we observe sharply declining discount rates in the very short run, and then discount rates asymptoting towards δ as the effect of the initial drop in the discount factor diminishes. The drop in the discount factor caused by β can be viewed as fixed utility cost of discounting anything

[17] There are many variants from the exponential model, and most are evaluated by Andersen, Harrison, Lau and Rutström [2014] using a separable and additive intertemporal utility function.

relative to the present, since it does not vary with the horizon t once $t>0$.

The QH model performs poorly in our model with intertemporal risk aversion, in the sense that the coefficient β is not significantly different from 1, which of course is the exponential case.[18] We estimate the value to be 1.003, with a 95% confidence interval between 0.989 and 1.018. The estimated values for r, δ and η are virtually identical to those shown in Table 1 for the exponential specification, which is of course not surprising if $\beta \approx 1$.

The discount factor for the Weibull distribution from statistics[19] is defined as

$$D^W(t) = \exp(-\acute{r} t^{1/\acute{s}}) \tag{19}$$

for $\acute{r} > 0$ and $\acute{s} > 0$. For $\acute{s}=1$ this collapses to the exponential specification, and hence the parameter $\acute{s}$ can be viewed as reflecting the "slowing down" or "speeding up" of time as subjectively perceived by the individual. This specification is due to Read [2001; p. 25, equation (16)]. The discount rate at time t in the Weibull specification is then

$$d^W(t) = \exp(\acute{r} t^{(1-\acute{s})/\acute{s}}) - 1 \tag{20}$$

Thus one can again see the exponential emerge as a special case when $\acute{s}=1$.

The Weibull model also performs poorly in our data, in the sense that the key parameter $\acute{s}$ is estimated to be 1.048, with a standard error of 0.141 and a 95% confidence interval between 0.77 and 1.32. This uncertainty in the estimate of $\acute{s}$ does translate into some uncertainty about discount rates in the short-run, but not in an economically significant way. For horizons of 1 week the implied discount rate is 0.137, for 3 months it is 0.121, and for 1 year it is 0.113; the confidence intervals for these estimates are -0.013 ↔ 0.288, 0.069 ↔ 0.173 and 0.092 ↔ 0.135, respectively. Again, the estimates of r, δ

[18] The QH model performs poorly with these data even when one assumes intertemporal risk neutrality: see Andersen, Harrison, Lau and Rutström [2014].

[19] Any probability density function f(t) defined on [0, ∞) can form the basis of a discounting function by taking the integral of f(t) between t and ∞. Indeed, discounting functions are formally identical to the "survivor functions" that labor and health economists routinely estimate in duration models, and are also known as "reliability functions" in the applied statistics literature on failure. Hence familiar and flexible families of probability density functions, such as the Gamma or Weibull, can be used to directly define discounting functions. This has the attraction of allowing the analyst to rely on a large literature in statistics on the properties of these functions for different inferential purposes.

and η are virtually identical to those shown in Table 1 for the exponential specification.

One implication of these non-exponential specifications, as noted by Backus, Routledge and Zin [2004; p. 328], is non-stationarity and time inconsistency. We do not want to rule that behavioral possibility out *a priori*, but others might want to.[20] If so, there exist general restrictions on the intertemporal utility function in order to ensure stationary preferences and time consistency, even when allowing for correlation aversion (e.g., see Bommier [2013], Bommier and Le Grand [2014] and Epstein, Fahri and Strzalecki [2014]).

E. Non-Expected Utility Theory

Similarly, we can show that the concept of intertemporal correlation aversion does not depend on the use of the EUT model.[21] To concretely illustrate this, we consider the effect of using a popular alternative model due to Quiggin [1982] which relaxes the IA. The RDU model posits probability weights based on some continuous function of the objective probabilities, and then infers decisions weights from these probability weights. The probability and decision weights depend on the rank of the outcome, in a familiar manner, replacing the usual IA with a Comonotonic IA. If the atemporal expected utility function is

$$\mathrm{EU} = [p(z) \times U(z)] + [p(Z) \times U(Z)], \tag{21}$$

then if $Z > z$, we can rewrite the atemporal expected utility as

$$\mathrm{RDU} = [(1-\omega(p(Z)) \times U(z)] + [\omega(p(Z)) \times U(Z)] \tag{22}$$

for some probability weighting function $\omega(p)$. We use a general functional form proposed by Prelec [1998] that exhibits considerable flexibility:

[20] Indeed, we find it natural to think of there being a (statistical) mixture of data-generating processes at work, particularly in aggregate, representative agent models. One process might be time-consistent and another process might not be, as in Coller, Harrison and Rutström [2012]. To study such mixtures, one must be able to specify different discounting functions that allow such behavior.

[21] There have been extensions of multiattribute utility theory to a wide range of non-EUT models, such as Fishburn [1984] and Miyamoto and Wakker [1996].

$$\omega(p) = \exp\{- \zeta \, (-\ln p)^{\upsilon}\}, \tag{23}$$

defined for $0<p\leq 1$, $\zeta > 0$ and $\upsilon > 0$.[22] Of course, EUT assumes the identity function $\omega(p)=p$, which is the case when $\zeta = \upsilon = 1$.

When the outcome is simply an amount of money, as in our atemporal lottery tasks, there is no complication calculating the rank in order to apply the RDU model. When the outcome consists of two time-dated amounts of money, as in our temporal lottery tasks, one has to be more careful. The natural quantity to base the rank on is then the present value of the atemporal utilities afforded by the two time-dated amounts of money. To see this explicitly, recall the expression for option A, referred to generically as lottery α in the definition of correlation aversion:

$$PEU_A = p(L_t , S_{t+\tau})\times[\, \xi(L_t, S_{t+\tau})^{(1-\eta)}/(1-\eta) \,] + p(S_t, L_{t+\tau})\times[\, \xi(S_t, L_{t+\tau})^{(1-\eta)}/(1-\eta) \,] \tag{10}$$

Since the decision tasks are designed such that $S_t=S_{t+\tau}$ and $L_t=L_{t+\tau}$., we get that $\xi\,(L_t, S_{t+\tau})>\xi\,(S_t, L_{t+\tau})$ for $\delta>0$, and the rank-dependent utility, with just two outcomes, is

$$PRDU_A = \omega(p(X, y)\times[\, \xi(L_t, S_{t+\tau})^{(1-\eta)}/(1-\eta) \,] + (1-\omega(p(X, y)))\times[\, \xi(S_t, L_{t+\tau})^{(1-\eta)}/(1-\eta) \,] \tag{10$'$}$$

A similar construction applies for option B, and one can trivially identify the ranks on an *a priori* basis.

The estimates show evidence of greater correlation aversion when one allows for RDU preferences rather than EUT risk preferences. Figure 3 shows the estimated "S-shaped" probability weighting function, and the decision weights implied for equi-probable reference lotteries (e.g., if there are 4 prizes each has probability ¼).[23] The estimated values of ζ and υ are 1.37 and 2.32, respectively, and one can easily reject the EUT hypothesis that $\zeta = \upsilon = 1$. There are some slight changes in the other

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[22] Many apply the Prelec [1998; Proposition 1, part (B)] function with constraint $0 < \upsilon < 1$, which requires that the probability weighting function exhibit subproportionality (so-called "inverse-S" weighting). Contrary to received wisdom, many individuals exhibit estimated probability weighting functions that violate subproportionality, so we use the more general specification from Prelec [1998; Proposition 1, part (C)], only requiring $\upsilon > 0$, and let the evidence determine if the estimated υ lies in the unit interval. This seemingly minor point makes a major difference in our case: constraining υ to the unit interval incorrectly leads to evidence of *no* probability weighting for the average adult Dane.

[23] In general, when there are more than two outcomes, there is a distinction between the probability weighting function $\omega(p)$ and the decisions weights $w(p)$ derived from them. When there are just two prizes, as here, the decision weights for the highest and lowest outcome are $\omega(p)$ and $1-\omega(p)$.

core structural parameters from Table 1: r is now estimated to be 0.46, δ is estimated to be 0.093, and η is estimated to be 0.47. Yet again we have evidence of statistically significant correlation aversion for the average adult Dane.

5. Conclusions

We elicit intertemporal risk attitudes from a representative sample of the adult Danish population using real economic commitments and a theoretical framework derived from well-known multiattribute theory. The results suggest that intertemporal risk aversion is a better characterization of the average Dane than intertemporal risk neutrality. This result implies that the convenient additive specification of the intertemporal utility function is not an appropriate representation of intertemporal preferences for the general Danish population. We also show that the characterization of intertemporal risk aversion leads to significantly different estimates of risk premia, compared to the estimates obtained when one assumes it away. Our findings have important implications for the characterization of intertemporal preferences in life-cycle modeling, labor supply over time, retirement planning, and policy applications with varying time profiles of costs and benefits.

At a methodological level our approach to estimating correlation aversion complements the earliest work of Keeney [1971][1972][1973][1977] and Keeney and Raiffa [1976] on the direct assessment of multiattribute utility functions. Much of the literature on empirical demand systems in the 1950s and 1960s used utility structures exhibiting separability and additivity to facilitate estimation (Deaton and Muellbauer [1980; ch. 3, 5]), and early work on utility independence was explicitly motivated by the desire to *directly* elicit multiattribute utility specifications in an efficient manner. Our approach is to *indirectly* elicit those specifications, by estimating a latent structure consistent with observed binary choices over carefully selected time-dated lotteries. We still need to attend to the same general issues of identification, but in a way that is arguably less demanding of the subject. Moreover, we are free to explore alternative models of time preferences and risk preferences, as demonstrated, whereas direct elicitation requires that one take a stance on those prior to observation of subject behavior.

Finally, the multiattribute utility structure we employ is general, and not a theoretical framework constructed just to address specific anomalies in intertemporal choice behavior. The concept of correlation aversion has much wider applicability than to evaluating risk attitudes towards income streams over time.

For example, Bommier [2006][2010][2013] applies it to the idea that agents know that they have finite lives, but do not know *when* they will die. This is a naturally-occurring and pervasive time-dated risk, and concepts of correlation aversion then have sharp implications for the characterization of discounting, portfolio choice, and life-cycle behavior. One could easily imagine extensions of this application to consider risk management choices, in the form of investments in health or location to improve one's chances of living longer. Or extensions to consider another attribute, the quality of life, as well as longevity *per se*.

In terms of a-temporal correlation aversion, Keeney [1977] and Keeney and Raiffa [1976] document a wide range of policy applications in which these concepts naturally apply. For example, Gangadharan, Harrison and Leroux [2015] consider donor preferences over aid to developing countries that is reasonably expected to have risky outcomes over multiple attributes, in their case access to water to meet basic needs on the one hand and the improvement of sanitation outcomes on the other hand. They find that private donors exhibit correlation *aversion* over these attributes when making donation decisions, in contrast to aid agencies which tend to promote the complementarity of different attributes of aid of this kind that would be better suited to donors that were correlation *loving*. Thus the concept of correlation aversion would help in the design of better matches between philanthropic donors and aid providers.

As a final, normative example, consider the issue of evaluating the welfare cost of "poverty spells," defined as transient dips below the (absolute or relative) poverty line. Figure 4, extracted from

Calvo and Dercon [2009] illustrates with different temporal patterns of consumption, with z denoting a poverty line. Consider the left 4 hypothetical scenarios, and take scenario 4.a as the benchmark. By comparison, do we say that period-long poverty is less in scenario 4.b just because the periods of "compensation" provide more consumption than scenario 4.a? If so, how are we to evaluate how much compensation of this kind would offset the episodic poverty? Is scenario 4.c worse than 4.a because the poverty spells arise sooner in time? Similarly is scenario 4.d better than 4.a since the poverty spells occur later in time, or is that offset by them being contiguous? And what if these four scenarios are equally likely at the outset, and the specific levels of consumption within each year also random around these means? The right 4 scenarios are taken from field data for specific rural households in different locations in Ethiopia, showing that there can be considerable variety in poverty spells. Whether we are using the risk and time preferences of the households to evaluate these alternatives, or some social welfare function reflecting the preferences of donors or governments, rigorous evaluation of these poverty spells requires a general structure that allows correlation aversion, and that is flexible enough to accommodate a wide range of models of risk and time preferences.

Table 1: Maximum Likelihood Estimates Assuming CRRA Atemporal Utility Function

N=49,560 observations, based on 413 subjects

Parameter	Point Estimate	Standard Error	*p*-value	95% Confidence Interval	
			A. Atemporal Utility Function		
r	0.35	0.037	<0.001	0.28	0.42
μ^{RA}	0.18	0.011	<0.001	0.16	0.20
			B. Discounting Function		
δ	0.114	0.012	<0.001	0.092	0.137
μ^{DR}	0.04	0.003	<0.001	0.03	0.04
			C. Intertemporal Utility Function		
η	0.32	0.044	<0.001	0.23	0.40
μ^{SDR}	0.18	0.010	<0.001	0.16	0.20
			D. Implied Estimates		
RRA	0.45	0.030	<0.001	0.39	0.51
1/RRA	2.21	0.147	<0.001	1.92	2.50
IES	2.85	0.305	<0.001	2.62	3.45
IES − 1/RRA	0.65	0.186	<0.001	0.28	1.01

Figure 1: Estimated Risk Premia

Prize sets in Option B of the intertemporal risk aversion task. Risk Premia for the correlation neutral (CN) case derive only from atemporal risk aversion; risk premia for the correlation averse (CA) case derive from both intertemporal and atemporal risk aversion.

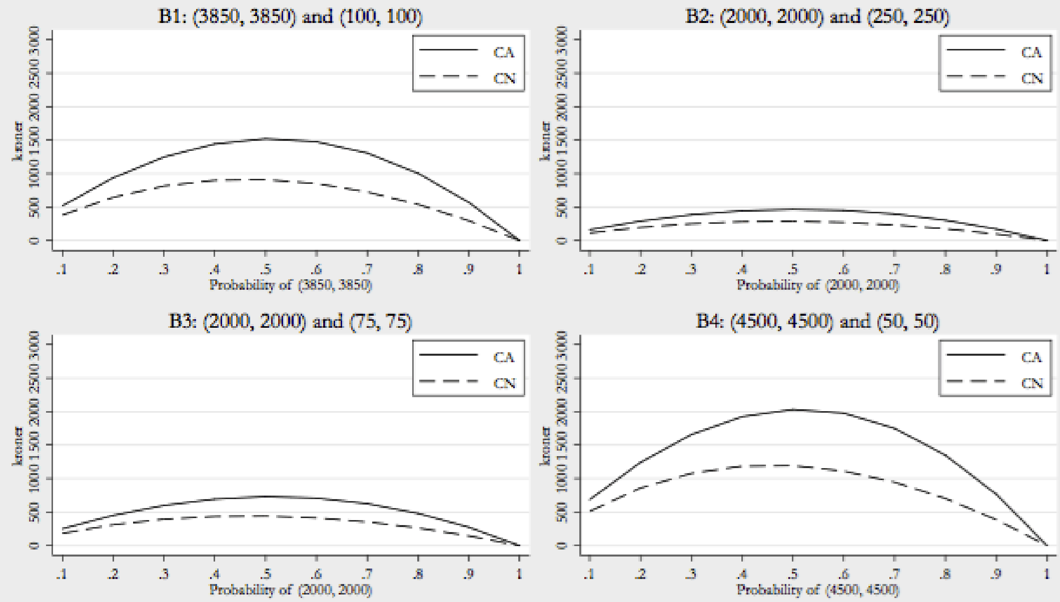


Figure 2: Distribution of the Coefficient of Correlation Aversion

Predicted values based on ML estimates with observable demographics; N=413

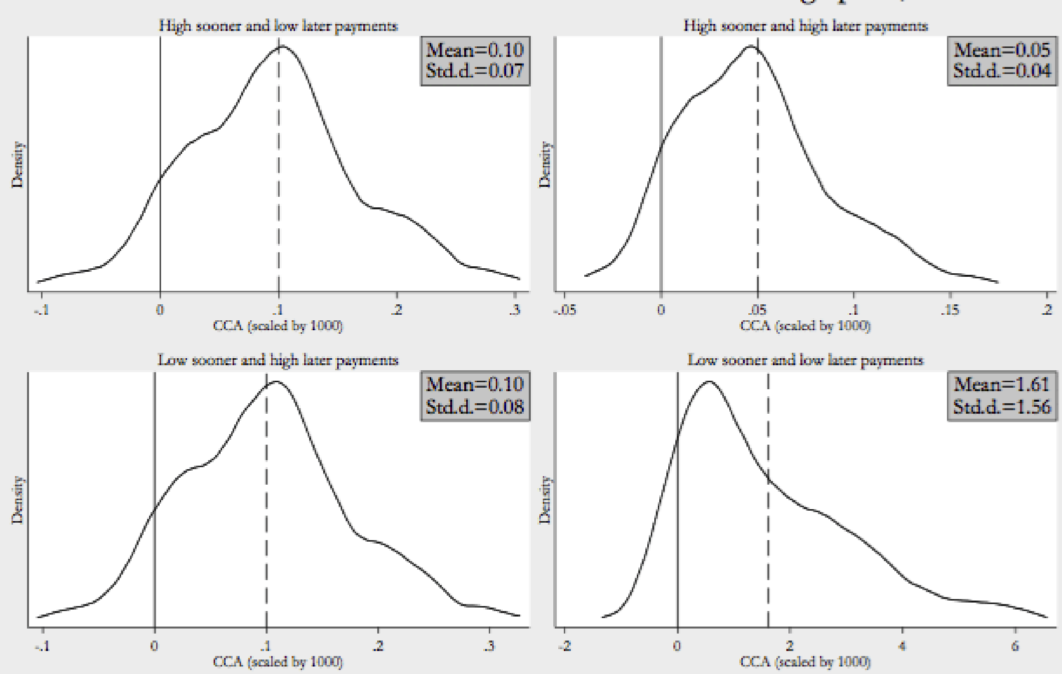


Figure 3: Probability Weighting and Implied Decision Weights

Decision weights based on equi-probable reference lotteries

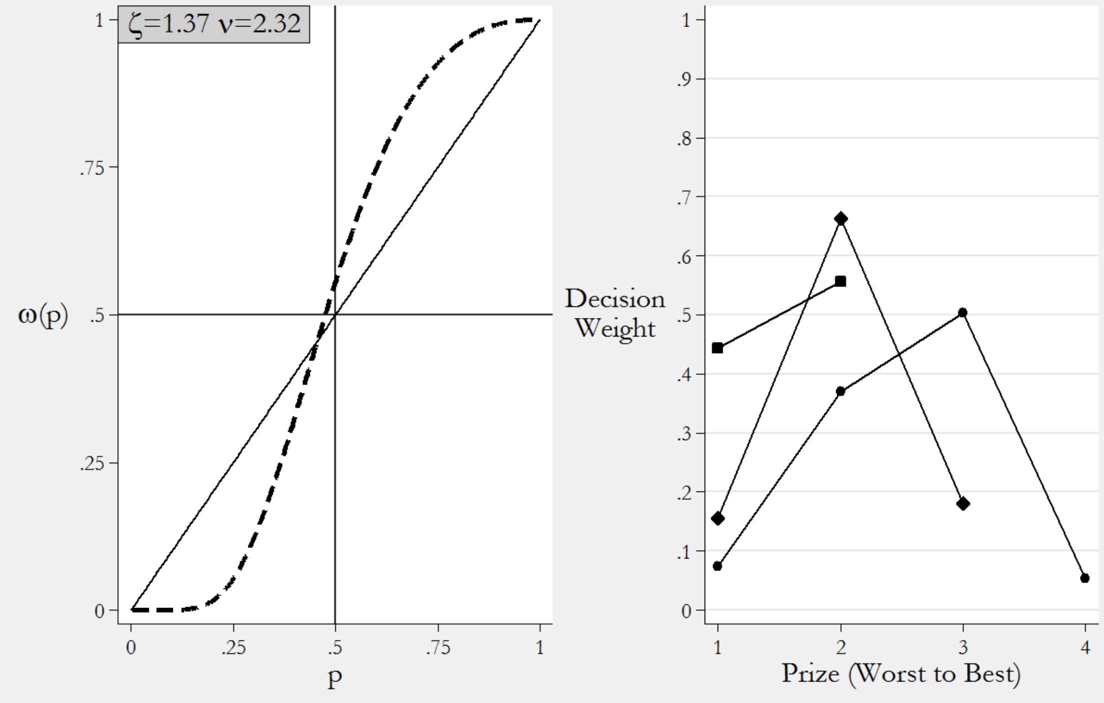
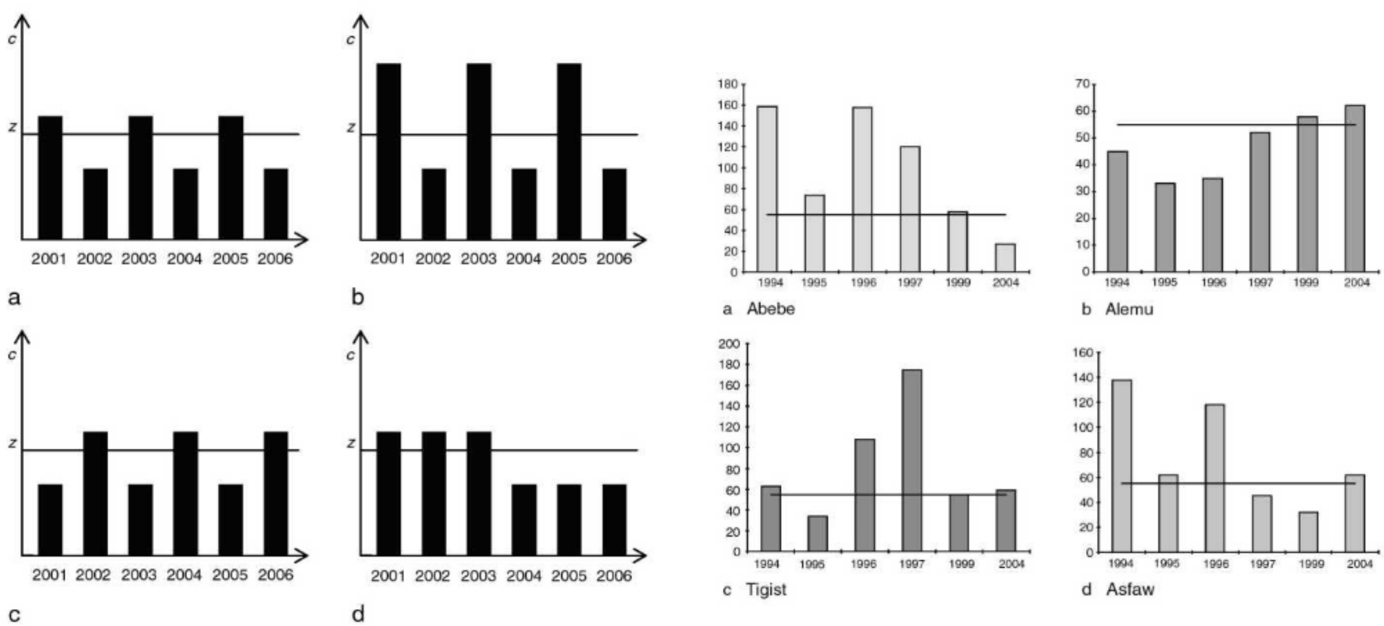


Figure 4: Illustrative and Empirical Examples of Poverty Spells

Source: Calco and Dercon [2009; Figures 2.1 and 2.2]



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Appendix A: Instructions (WORKING PAPER)

We document the instructions by first listing the "manuscript" that shows what was given to subjects and read to them, and then we document some of the screen displays. The original Danish manuscript is available on request. The originals were in 14-point font, printed on A4 paper for nice page breaks (a horizontal line below indicates a page break), and given to subjects in laminated form. The manuscript below was for the sessions in which the discount rate task was presented first. After these experimental tasks were completed there were additional tasks in the session that are not relevant here.

A. Experimental Manuscript

Welcome announcement

[Give informed consent form to subjects.]

Thank you for agreeing to participate in this survey. The survey is financed by the Social Science Research Council and the Carlsberg Foundation and concerns the economics of decision making.

Before we begin the survey, let me read out the informed consent form that is handed out to you. This form explains your rights as a participant in the survey, what the survey is about and how we make payments to you.

[Read the informed consent form.]

Is everyone able to stay for the full two hours of the meeting? Before we begin, I will ask each of you to pick an envelope from me. The envelope contains a card with an ID number that we will use to keep track of who answered which questions. All records and published results will be linked to anonymous ID numbers only, and not to your name. Please keep your ID numbers private and do not share the information with anyone else.

[Each subject picks an envelope.]

You will be given written instructions during the survey, but make all decisions on the computer in front of you. Please enter your ID number on the computer in front of you, but keep the card for later use.

You will now continue with the first task. The problem is not designed to test you. The only right answer is what you really would choose. That is why the task gives you the chance of winning money. I will now distribute the instructions and then read it out loud.

[Give IDR instructions to subjects.]
[Read the IDR instructions.]

Task D

In this task you will make a number of choices between two options labeled “A” and “B”. An example of your task is shown on the right. You will make all decisions on a computer.

All decisions have the same format. In the example on the right Option A pays 100 kroner today and Option B pays 105 kroner twelve months from now. By choosing option B you would get an annual return of 5% on the 100 kroner.

We will present you with 40 of these decisions. The only difference between them is that the amounts and payment dates in Option A and B will differ.

You will have a 1-in-10 chance of being paid for one of these decisions. The selection is made with a 10-sided die. If the roll of the die gives the number 1 you will be paid for one of the 40 decisions, but if the roll gives any other number you will not be paid. If you are paid for one of these 40 decisions, then we will further select one of these decisions by rolling a 4-sided and a 10-sided die. When you make your choices you will not know which decision is selected for payment. You should therefore treat each decision as if it might actually count for payment.

You will receive the money on the date stated in your preferred option. If you receive some money today, then it is paid out at the end of the experiment. If you receive some money to be paid in the future, then it is transferred to your personal bank account on the specified date. In that case you will receive a written confirmation from Copenhagen Business School which guarantees that the money is reserved on an account at Danske Bank. You can send this document to Danske Bank in a prepaid envelope, and the bank will transfer the money to your account on the specified date.

Before making your choices you will have a chance to practice so that you better understand the consequences of your choices. Please proceed on the computer to the practice task. You will be paid in caramels for this practice task, and they are being paid on the time stated in your preferred option.

[Subjects make decisions in the practice IDR task.]

I will now come around and pay you in caramels for your choice of A or B. Please proceed to the actual task after your earnings are recorded. You will have a 1-in-10 chance of being paid for one of the 40 decisions in the actual task.

Password 1:____

[Subjects make decisions in the actual IDR task.]

I will now come around and ask you to roll a 10-sided die to determine if you are being paid for one of the decisions. If the roll of the die gives the number 1 you will be paid for one of the 40 decisions, but if the roll gives any other number you will not be paid. If you are paid for one of the 40 decisions, then I will ask you to roll a 4-sided and a 10-sided die to select one of the decisions for payment.

Password 2:____

[Roll 10-sided die to determine if they are being paid.]
[Roll 4-sided and 10-sided dice to determine the decision for payment.]

You will now continue with the second task. I will distribute the instructions and then read it out loud.

[Give RA instructions to subjects.]
[Read the RA instructions.]

Task L

In this task you will make a number of choices between two options labeled "A" and "B". An example of your task is shown on the right. You will make all decisions on a computer.

All decisions have the same format. In the example on the right Option A pays 60 kroner if the outcome of a roll of a ten-sided die is 1, and it pays 40 kroner if the outcome is 2-10. Option B pays 90 kroner if the outcome of the roll of the die is 1 and 10 kroner if the outcome is 2-10. All payments in this task are made today at the end of the experiment.

We will present you with 40 such decisions. The only difference between them is that the probabilities and amounts in Option A and B will differ.

You have a 1-in-10 chance of being paid for one of these decisions. The selection is made with a 10-sided die. If the roll of the die gives the number 1 you will be paid for one of the 40 decisions, but if the roll gives any other number you will not be paid. If you are paid for one of these 40 decisions, then we will further select one of these decisions by rolling a 4-sided and a 10-sided die. A third die roll with a 10-sided die determines the payment for your choice of Option A or B. When you make your choices you will not know which decision is selected for payment. You should therefore treat each decision as if it might actually count for payment.

If you are being paid for one of the decisions, we will pay you according to your choice in the selected decision. You will then receive the money at the end of the experiment.

Before making your choices you will have a chance to practice so that you better understand the consequences of your choices. Please proceed on the computer to the practice task. You will be paid in caramels for this practice task.

[Subjects make decisions in the practice RA task.]

I will now come around and pay you in caramels for your choice of A or B. I will ask you to roll a 10-sided die to determine the payment for your choice of A or B. Please proceed to the actual task after your earnings are recorded. You will have a 1-in-10 chance of being paid for one of the 40 decisions in the actual task.

Password 3:____

[Subjects make decisions in the actual RA task.]

I will now come around and ask you to roll a 10-sided die to determine if you are being paid for one of the decisions. If the roll of the die gives the number 1 you will be paid for one of the 40 decisions, but if the roll gives any other number you will not be paid. If you are paid for one of the 40 decisions, then I will ask you to roll a 4-sided and a 10-sided die to select one of the decisions for payment. A third die roll with a 10-sided die determines the payment for your choice of Option A or B.

Password 4:____

[Roll 10-sided die to determine if they are being paid.]
[Roll 4-sided and 10-sided dice to determine the decision for payment.]
[Roll 10-sided die to determine payment in Option A and B.]

You will now continue with the third task. I will distribute the instructions and then read it out loud.

[Give RA-IDR instructions to subjects.]
[Read the RA-IDR instructions.]

Task DL

In this task you will make a number of choices between two options labeled “A” and “B”. An example of your task is shown on the right. You will make all decisions on a computer.

All decisions have the same format. In the example on the right Option A pays 100 kroner today and 5 kroner in twelve months from now if the outcome of a roll of a ten-sided die is 1, and it pays 5 kroner today and 100 kroner in twelve months if the outcome is 2-10. Option B pays 100 kroner today and 100 kroner in twelve months if the outcome of the roll of the die is 1, and it pays 5 kroner today and 5 kroner in twelve months if the outcome is 2-10.

We will again present you with 40 of these decisions. The only difference between them is that the probabilities, amounts and payment dates in Option A and B will differ.

You have a 1-in-10 chance of being paid for one of these decisions. The selection is made with a 10-sided die. If the roll of the die gives the number 1 you will be paid for one of the 40 decisions, but if the roll gives any other number you will not be paid. If you are paid for one of these 40 decisions, then we will further select one of these decisions by rolling a 4-sided and a 10-sided die. A third die roll with a 10-sided die determines the payment for your choice of Option A or B. When you make your choices you will not know which decision is selected for payment. You should therefore treat each decision as if it might actually count for payment.

You will receive the money on the date stated in your preferred option. If you receive some money today, then it is paid out at the end of the experiment. If you receive some money to be paid in the future, then it is transferred from Copenhagen Business School’s account at Danske Bank to your personal bank account on the specified date. In that case you will receive a written confirmation from Copenhagen Business School which documents the size of your earnings, and when the money is being transferred. You can send this document to Danske Bank in a prepaid envelope, and the bank will transfer the money to your account on the specified date.

Before making your choices you will have a chance to practice so that you better understand the consequences of your choices. Please proceed on the computer to the practice task. You will be paid in caramels for this practice task, and they are being paid on the time stated in your preferred option.

[Subjects make decisions in the practice RA-IDR task.]

I will now come around and pay you in caramels for your choice of A or B. I will ask you to roll a 10-sided die to determine the payment for your choice of A or B. Please proceed to the actual task after your earnings are recorded. You will have a 1-in-10 chance of being paid for one of the 40 decisions in the actual task.

Password 5:____

[Subjects make decisions in the actual RA-IDR task.]

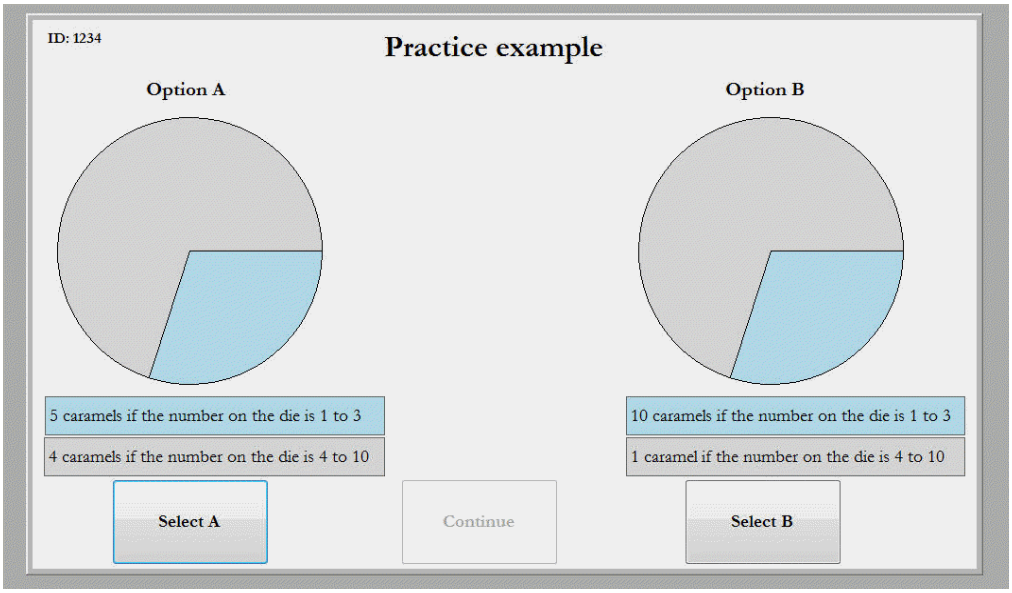
I will now come around and ask you to roll a 10-sided die to determine if you are being paid for one of the decisions. If the roll of the die gives the number 1 you will be paid for one of the 40 decisions, but if the roll gives any other number you will not be paid. If you are paid for one of the 40 decisions, then I will ask you to roll a 4-sided and a 10-sided die to select one of the decisions for payment. A third die roll with a 10-sided die determines the payment for your choice of Option A or B.

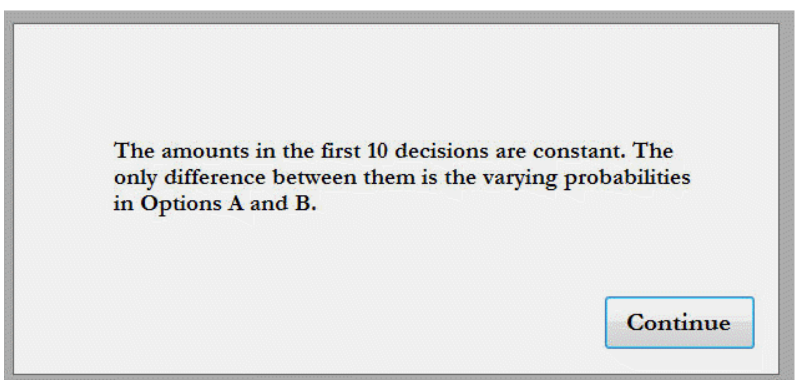
Password 6:____

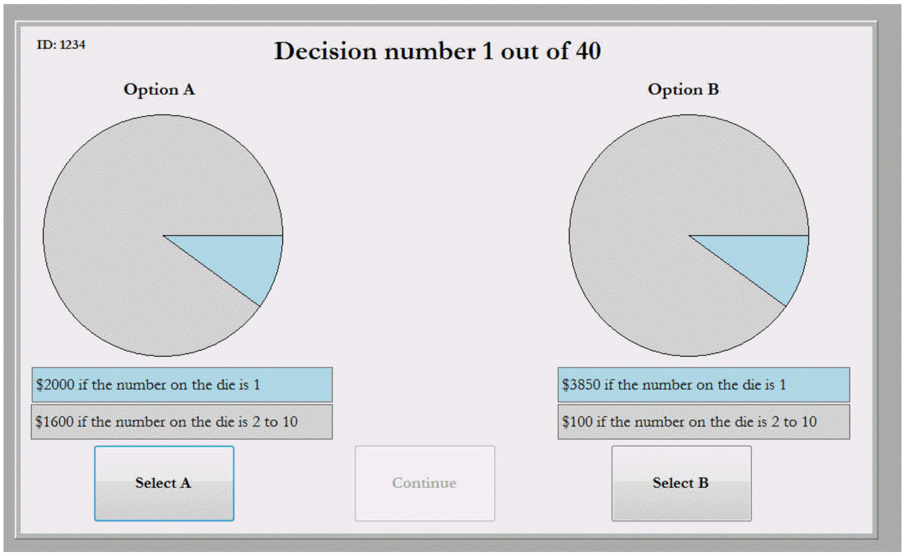
[Roll 10-sided die to determine if they are being paid.]
[Roll 4-sided and 10-sided dice to determine the decision for payment.]
[Roll 10-sided die to determine payment in Option A and B.]

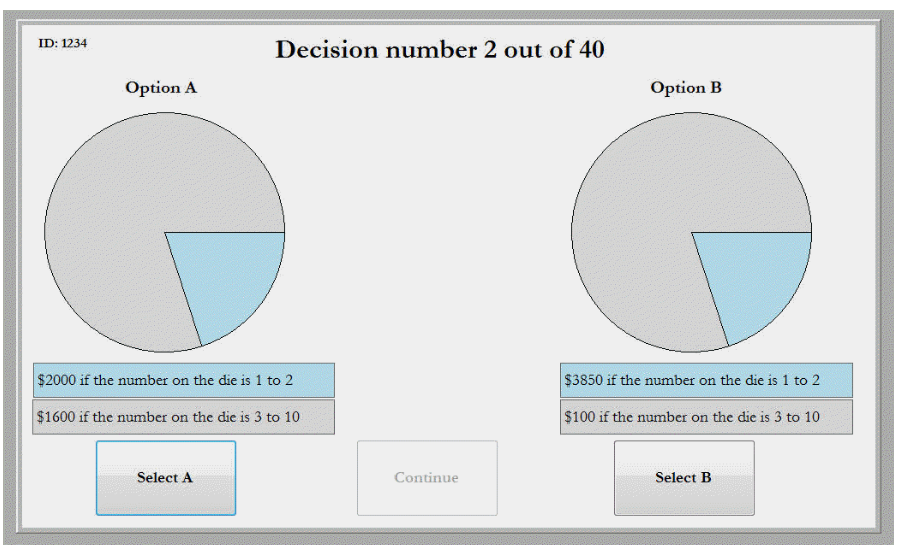
B. Typical Screen Shots for Lottery Choices

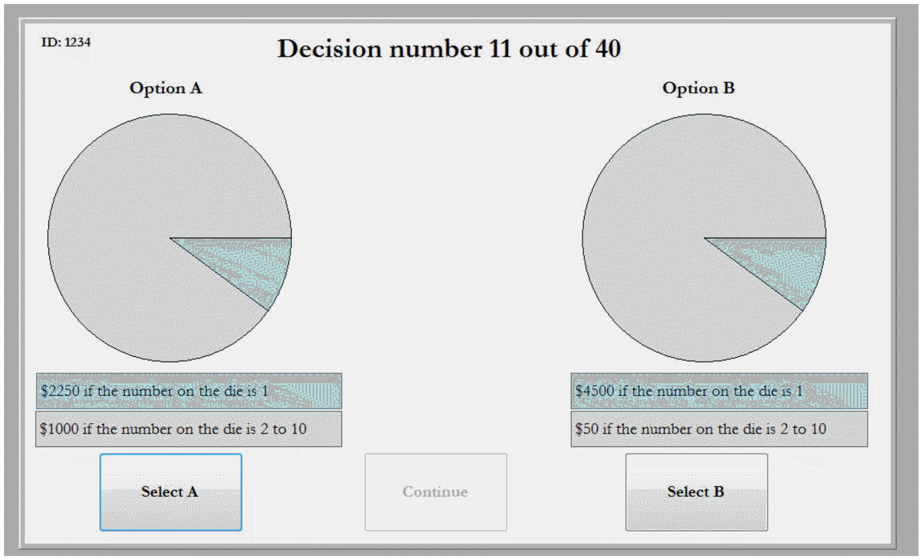
The first screen shot on the next page shows the full screen within which the text box is contained, so that one gets an impression of what the subject encountered in all screen shots. Then we display more detailed screen shots of the practice example and the first few lottery choices. Prior to each block of 10 lottery choices the subject was told that the lottery prizes for the next 10 choices would stay the same and the only thing that would vary would be the probabilities. We then show the sequence of the first two lotteries, and then lottery 11 which uses new prizes.


ID: 1234
Practice example
Option A
Option B
5 caramels if the number on the die is 1 to 3
4 caramels if the number on the die is 4 to 10
10 caramels if the number on the die is 1 to 3
1 caramel if the number on the die is 4 to 10
Select A
Continue
Select B


The amounts in the first 10 decisions are constant. The only difference between them is the varying probabilities in Options A and B.
Continue


ID: 1234
Decision number 1 out of 40
Option A
Option B
$2000 if the number on the die is 1
$1600 if the number on the die is 2 to 10
$3850 if the number on the die is 1
$100 if the number on the die is 2 to 10
Select A
Continue
Select B


ID: 1234
Decision number 2 out of 40
Option A
Option B
$2000 if the number on the die is 1 to 2
$1600 if the number on the die is 3 to 10
$3850 if the number on the die is 1 to 2
$100 if the number on the die is 3 to 10
Select A
Continue
Select B

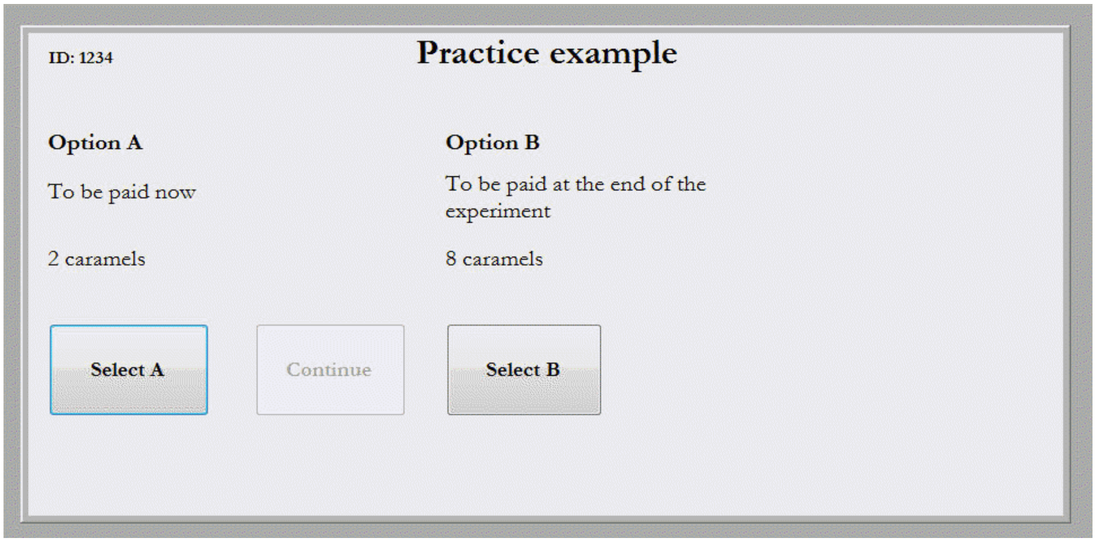


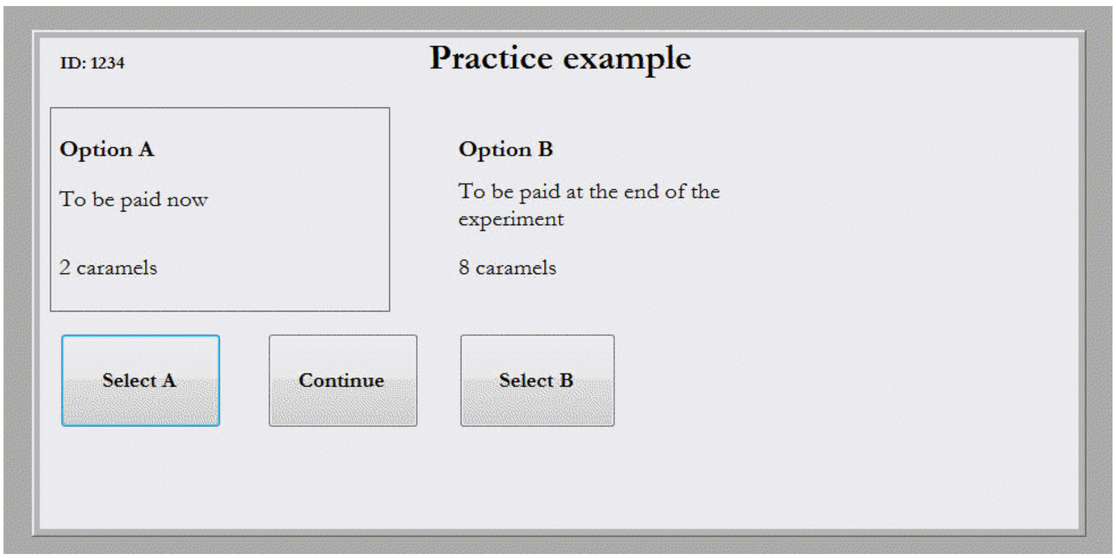
C. Typical Screen Shots for Discounting Choices

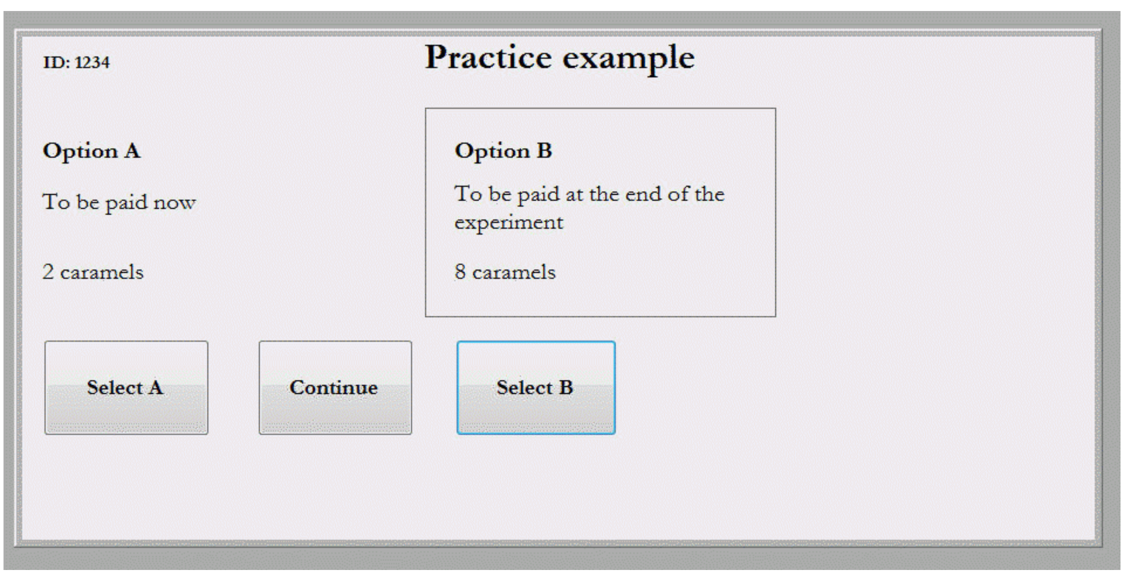
The next page shows the practice example provided at the beginning of these tasks. The top panel shows the initial screen shot, and then the next two panels show how the selected option is highlighted to make it clear to the subject which option is being selected.

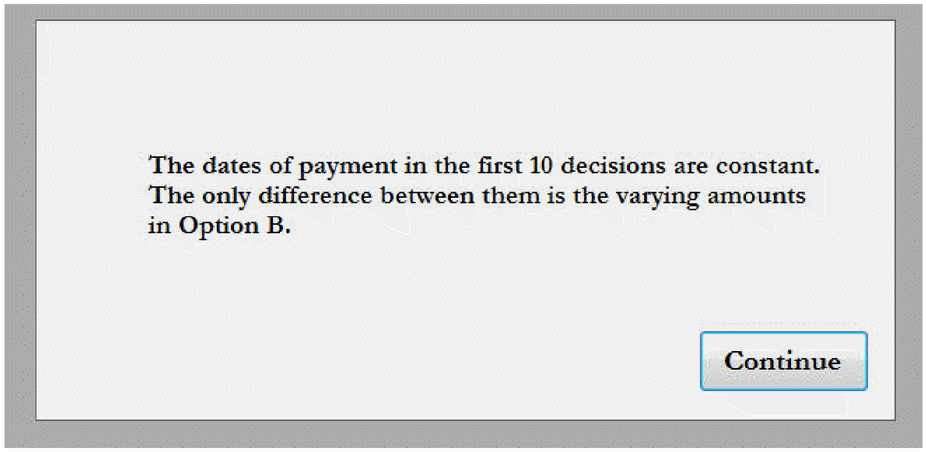
The following page shows the information that was given to each subject prior to each block of 10 choices. This information was that the principal and horizon would remain constant for the next 10 choices, but that the only thing that would change would be the amount in the "later" option. In these displays the implied interest rate is displayed.

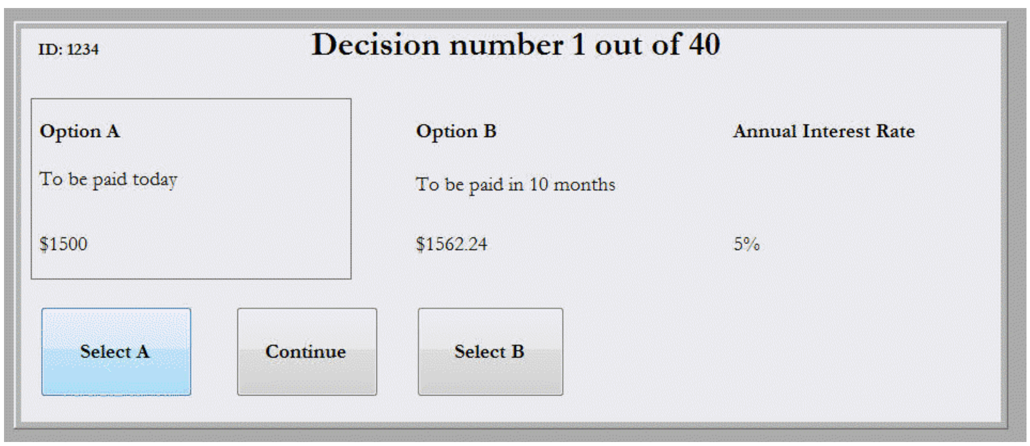
Finally, after the first 10 choices a new horizon was selected for the next 10 choices.

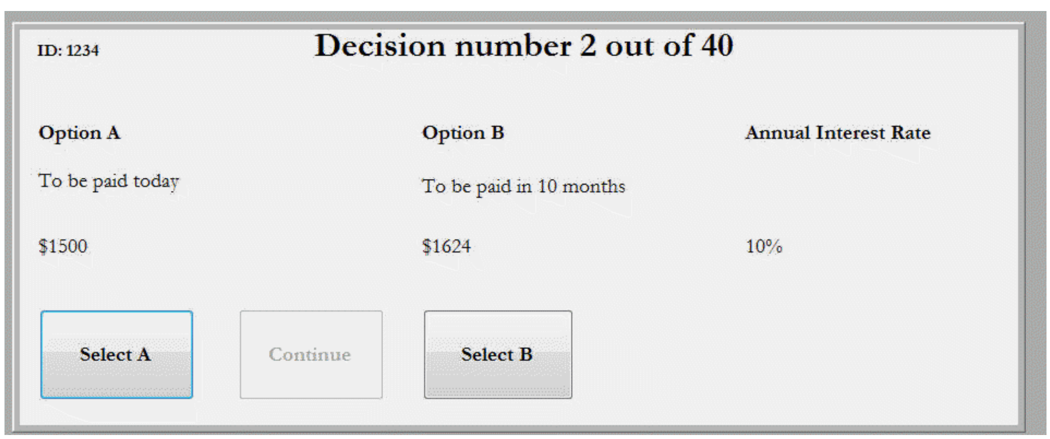

ID: 1234
Practice example
Option A
To be paid now
2 caramels
Option B
To be paid at the end of the experiment
8 caramels
Select A
Continue
Select B

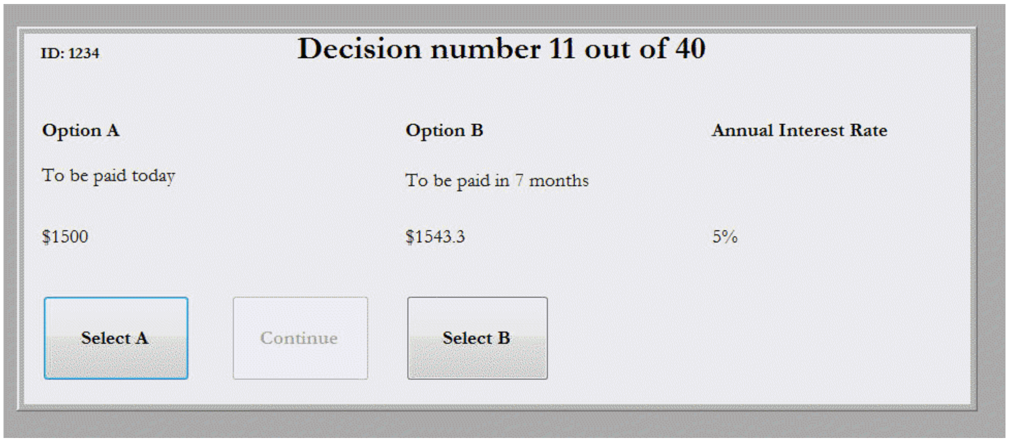

ID: 1234
Practice example
Option A
To be paid now
2 caramels
Option B
To be paid at the end of the experiment
8 caramels
Select A
Continue
Select B


ID: 1234
Practice example
Option A
To be paid now
2 caramels
Option B
To be paid at the end of the experiment
8 caramels
Select A
Continue
Select B


The dates of payment in the first 10 decisions are constant. The only difference between them is the varying amounts in Option B.
Continue


ID: 1234
Decision number 1 out of 40
Option A
To be paid today
$1500
Option B
To be paid in 10 months
$1562.24
Annual Interest Rate
5%
Select A
Continue
Select B

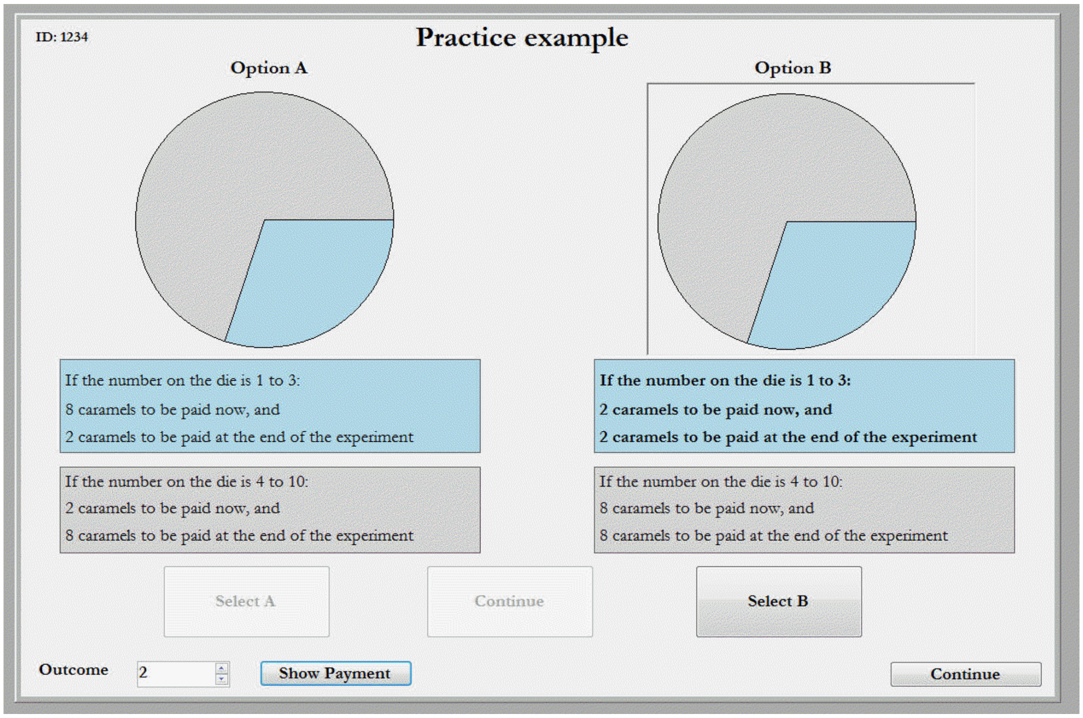

ID: 1234
Decision number 2 out of 40
Option A
To be paid today
$1500
Option B
To be paid in 10 months
$1624
Annual Interest Rate
10%
Select A
Continue
Select B

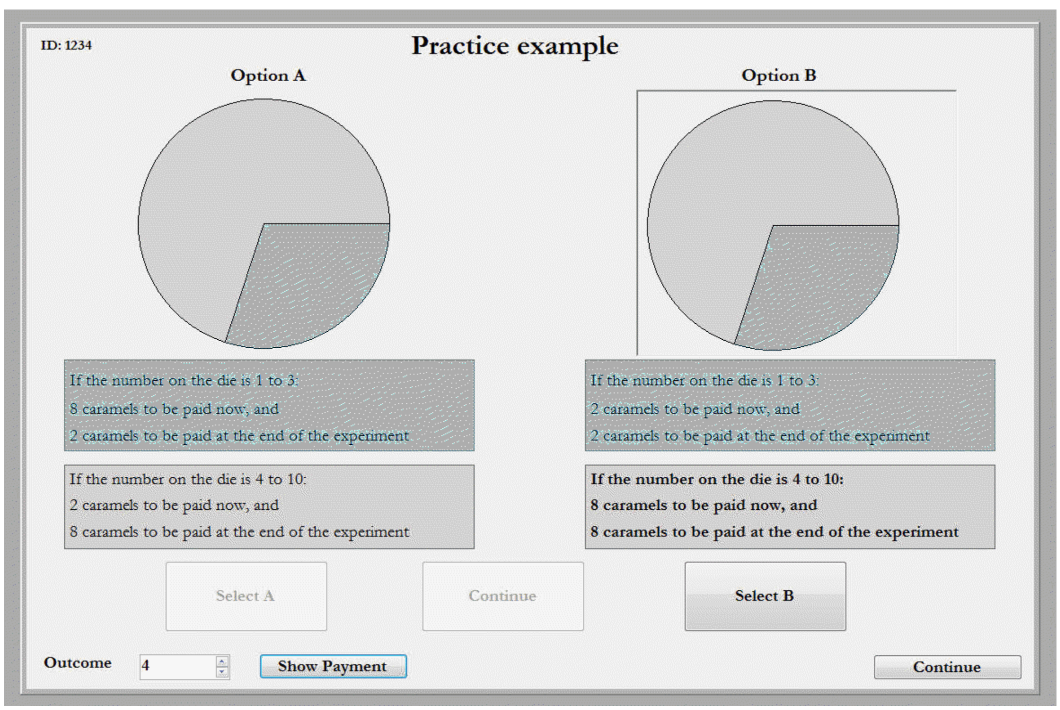


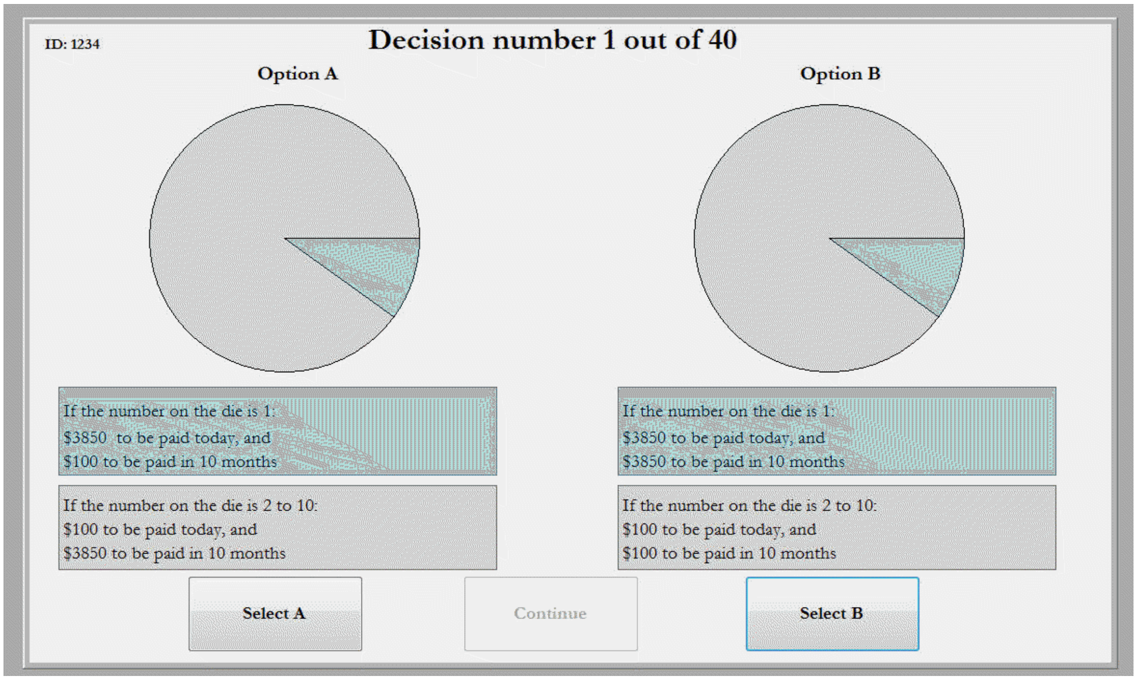
D. Typical Screen Shots for Intertemporal Risk Aversion Choices

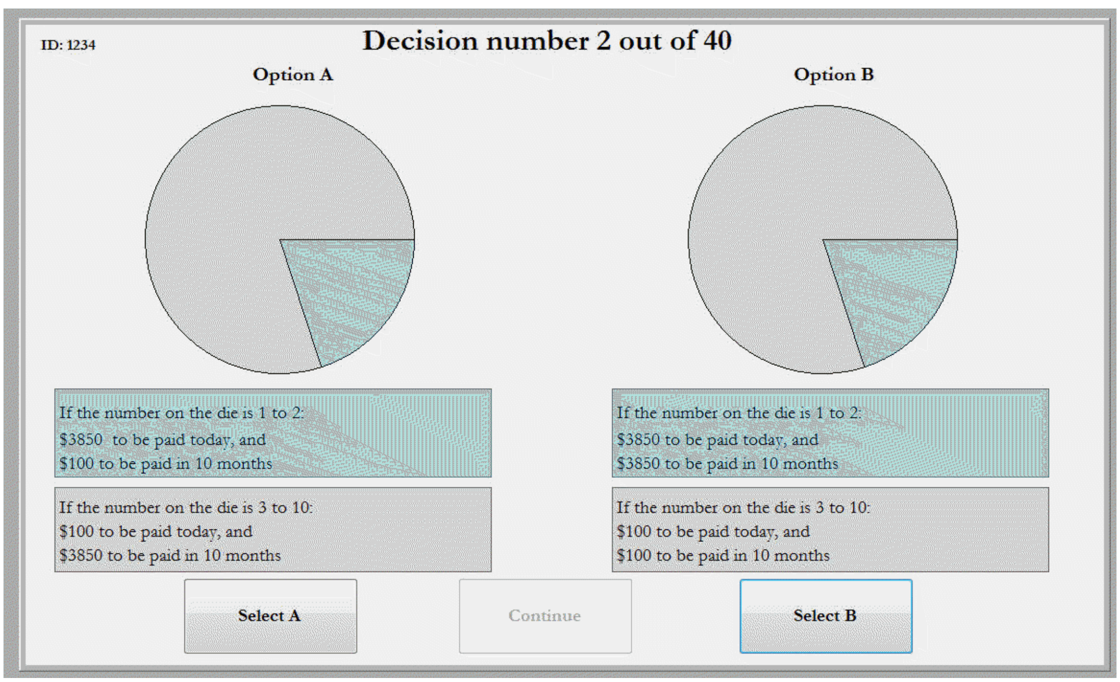
The next page shows the practice example provided at the beginning of these tasks. The top panel shows the initial screen shot, and then the next two panels show how the selected option is highlighted to make it clear to the subject which option is being selected.

The following page shows two of the actual tasks for a subject with no front end delay. The lottery prizes were always the same. Option A always had a mixture of the higher and smaller amount, with the first option having the higher amount sooner and the smaller amount later, and the second option having the lower amount sooner and the higher amount later. Option B always had the all-high or all-lower amounts.


ID: 1234
Practice example
Option A
Option B
If the number on the die is 1 to 3:
8 caramels to be paid now, and
2 caramels to be paid at the end of the experiment
If the number on the die is 4 to 10:
2 caramels to be paid now, and
8 caramels to be paid at the end of the experiment
If the number on the die is 1 to 3:
2 caramels to be paid now, and
2 caramels to be paid at the end of the experiment
If the number on the die is 4 to 10:
8 caramels to be paid now, and
8 caramels to be paid at the end of the experiment
Select A
Continue
Select B
Outcome
2
Show Payment
Continue


ID: 1234
Practice example
Option A
Option B
If the number on the die is 1 to 3:
8 caramels to be paid now, and
2 caramels to be paid at the end of the experiment
If the number on the die is 4 to 10:
2 caramels to be paid now, and
8 caramels to be paid at the end of the experiment
If the number on the die is 1 to 3:
2 caramels to be paid now, and
2 caramels to be paid at the end of the experiment
If the number on the die is 4 to 10:
8 caramels to be paid now, and
8 caramels to be paid at the end of the experiment
Select A
Continue
Select B
Outcome
4
Show Payment
Continue


ID: 1234
Decision number 1 out of 40
Option A
Option B
If the number on the die is 1:
$3850 to be paid today, and
$100 to be paid in 10 months
If the number on the die is 2 to 10:
$100 to be paid today, and
$3850 to be paid in 10 months
If the number on the die is 1:
$3850 to be paid today, and
$3850 to be paid in 10 months
If the number on the die is 2 to 10:
$100 to be paid today, and
$100 to be paid in 10 months
Select A
Continue
Select B


ID: 1234
Decision number 2 out of 40
Option A
Option B
If the number on the die is 1 to 2:
$3850 to be paid today, and
$100 to be paid in 10 months
If the number on the die is 3 to 10:
$100 to be paid today, and
$3850 to be paid in 10 months
If the number on the die is 1 to 2:
$3850 to be paid today, and
$3850 to be paid in 10 months
If the number on the die is 3 to 10:
$100 to be paid today, and
$100 to be paid in 10 months
Select A
Continue
Select B

E. Parameter Values

Table A1 shows the parameters of the lottery choice tasks, Table A2 shows the parameters of the discounting choice tasks, and Table A3 shows the parameters of the intertemporal risk aversion choices.

In Table A1 the parameters are (1) the decision number, (2) the probability of the high prize in each lottery, (3) the high prize of lottery A, in kroner, (4) the low prize of lottery A, in kroner, (5) the high prize of lottery B, in kroner, (6) the low prize of lottery B, in kroner, (7) the expected value of lottery A, and (8) the expected value of lottery B. The information in columns (7) and (8) was not presented to subjects.

Table A1: Parameters for Lottery Choices

Decision	Probability of High Prize	Lottery A High Prize	Lottery A Low Prize	Lottery B High Prize	Lottery B Low Prize	EV of Lottery A	EV of Lottery B
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	0.1	1125	750	2000	250	787.5	425
2	0.2	1125	750	2000	250	825	600
3	0.3	1125	750	2000	250	862.5	775
4	0.4	1125	750	2000	250	900	950
5	0.5	1125	750	2000	250	937.5	1125
6	0.6	1125	750	2000	250	975	1300
7	0.7	1125	750	2000	250	1012.5	1475
8	0.8	1125	750	2000	250	1050	1650
9	0.9	1125	750	2000	250	1087.5	1825
10	1	1125	750	2000	250	1125	2000
11	0.1	1000	875	2000	75	887.5	267.5
12	0.2	1000	875	2000	75	900	460
13	0.3	1000	875	2000	75	912.5	652.5
14	0.4	1000	875	2000	75	925	845
15	0.5	1000	875	2000	75	937.5	1037.5
16	0.6	1000	875	2000	75	950	1230
17	0.7	1000	875	2000	75	962.5	1422.5
18	0.8	1000	875	2000	75	975	1615
19	0.9	1000	875	2000	75	987.5	1807.5
20	1	1000	875	2000	75	1000	2000
21	0.1	2000	1600	3850	100	1640	475
22	0.2	2000	1600	3850	100	1680	850
23	0.3	2000	1600	3850	100	1720	1225
24	0.4	2000	1600	3850	100	1760	1600
25	0.5	2000	1600	3850	100	1800	1975
26	0.6	2000	1600	3850	100	1840	2350
27	0.7	2000	1600	3850	100	1880	2725
28	0.8	2000	1600	3850	100	1920	3100

29	0.9	2000	1600	3850	100	1960	3475
30	1	2000	1600	3850	100	2000	3850
31	0.1	2250	1000	4500	50	1125	495
32	0.2	2250	1000	4500	50	1250	940
33	0.3	2250	1000	4500	50	1375	1385
34	0.4	2250	1000	4500	50	1500	1830
35	0.5	2250	1000	4500	50	1625	2275
36	0.6	2250	1000	4500	50	1750	2720
37	0.7	2250	1000	4500	50	1875	3165
38	0.8	2250	1000	4500	50	2000	3610
39	0.9	2250	1000	4500	50	2125	4055
40	1	2250	1000	4500	50	2250	4500

In Table A2 the parameters are (1) the horizon in months, (2) the task number in sequence if this horizon was selected for the subject to make choices over, (3) the principal of 3000 kroner if the subject had the "higher stakes" condition, (4) the principal of 1500 kroner if the subject had the "lower stakes" condition, (5) the annual interest rate presented to the subject if that treatment was applied (this is also the annual effective rate with annual compounding), (6) the delayed payment if the subject had the "higher stakes" condition, (7) the delayed payment if the subject had the "lower stakes" condition, (8) the implied annual effective rate with quarterly compounding, and (9) the implied annual effective rate with daily compounding. The values in columns (8) and (9) were not presented to subjects.

Table A2: Parameters for Discounting Choices

Horizon in months	Task	Principal in high stakes	Principal if low stakes	Annual Interest Rate	Delayed Payment if low stakes	Delayed Payment if high stakes	AER Quarterly	AER Daily
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
0.5	1	3000	1500	5%	3006.10	1503.05	5.1%	5.1%
0.5	2	3000	1500	10%	3011.94	1505.97	10.4%	10.5%
0.5	3	3000	1500	15%	3017.52	1508.76	15.9%	16.2%
0.5	4	3000	1500	20%	3022.88	1511.44	21.6%	22.1%
0.5	5	3000	1500	25%	3028.02	1514.01	27.4%	28.4%
0.5	6	3000	1500	30%	3032.98	1516.49	33.5%	35.0%
0.5	7	3000	1500	35%	3037.75	1518.87	39.9%	41.9%
0.5	8	3000	1500	40%	3042.36	1521.18	46.4%	49.1%
0.5	9	3000	1500	45%	3046.81	1523.40	53.2%	56.8%
0.5	10	3000	1500	50%	3051.11	1525.56	60.2%	64.8%
1	1	3000	1500	5%	3012.22	1506.11	5.1%	5.1%
1	2	3000	1500	10%	3023.92	1511.96	10.4%	10.5%
1	3	3000	1500	15%	3035.14	1517.57	15.9%	16.2%
1	4	3000	1500	20%	3045.93	1522.96	21.6%	22.1%
1	5	3000	1500	25%	3056.31	1528.15	27.4%	28.4%

1	6	3000	1500	30%	3066.31	1533.16	33.5%	35.0%
1	7	3000	1500	35%	3075.97	1537.99	39.9%	41.9%
1	8	3000	1500	40%	3085.31	1542.65	46.4%	49.1%
1	9	3000	1500	45%	3094.34	1547.17	53.2%	56.8%
1	10	3000	1500	50%	3103.10	1551.55	60.2%	64.8%
2	1	3000	1500	5%	3024.49	1512.25	5.1%	5.1%
2	2	3000	1500	10%	3048.04	1524.02	10.4%	10.5%
2	3	3000	1500	15%	3070.70	1535.35	15.9%	16.2%
2	4	3000	1500	20%	3092.56	1546.28	21.6%	22.1%
2	5	3000	1500	25%	3113.67	1556.84	27.4%	28.4%
2	6	3000	1500	30%	3134.09	1567.05	33.5%	35.0%
2	7	3000	1500	35%	3153.87	1576.93	39.9%	41.9%
2	8	3000	1500	40%	3173.04	1586.52	46.4%	49.1%
2	9	3000	1500	45%	3191.65	1595.83	53.2%	56.8%
2	10	3000	1500	50%	3209.74	1604.87	60.2%	64.8%
3	1	3000	1500	5%	3036.82	1518.41	5.1%	5.1%
3	2	3000	1500	10%	3072.34	1536.17	10.4%	10.5%
3	3	3000	1500	15%	3106.67	1553.34	15.9%	16.2%
3	4	3000	1500	20%	3139.91	1569.95	21.6%	22.1%
3	5	3000	1500	25%	3172.11	1586.06	27.4%	28.4%
3	6	3000	1500	30%	3203.37	1601.68	33.5%	35.0%
3	7	3000	1500	35%	3233.74	1616.87	39.9%	41.9%
3	8	3000	1500	40%	3263.27	1631.64	46.4%	49.1%
3	9	3000	1500	45%	3292.03	1646.01	53.2%	56.8%
3	10	3000	1500	50%	3320.05	1660.02	60.2%	64.8%
4	1	3000	1500	5%	3049.19	1524.59	5.1%	5.1%
4	2	3000	1500	10%	3096.84	1548.42	10.4%	10.5%
4	3	3000	1500	15%	3143.07	1571.53	15.9%	16.2%
4	4	3000	1500	20%	3187.98	1593.99	21.6%	22.1%
4	5	3000	1500	25%	3231.65	1615.83	27.4%	28.4%
4	6	3000	1500	30%	3274.18	1637.09	33.5%	35.0%
4	7	3000	1500	35%	3315.63	1657.81	39.9%	41.9%
4	8	3000	1500	40%	3356.07	1678.03	46.4%	49.1%
4	9	3000	1500	45%	3395.55	1697.78	53.2%	56.8%
4	10	3000	1500	50%	3434.14	1717.07	60.2%	64.8%
5	1	3000	1500	5%	3061.61	1530.81	5.1%	5.1%
5	2	3000	1500	10%	3121.53	1560.77	10.4%	10.5%
5	3	3000	1500	15%	3179.89	1589.94	15.9%	16.2%
5	4	3000	1500	20%	3236.78	1618.39	21.6%	22.1%
5	5	3000	1500	25%	3292.31	1646.15	27.4%	28.4%
5	6	3000	1500	30%	3346.55	1673.28	33.5%	35.0%
5	7	3000	1500	35%	3399.59	1699.80	39.9%	41.9%
5	8	3000	1500	40%	3451.50	1725.75	46.4%	49.1%
5	9	3000	1500	45%	3502.34	1751.17	53.2%	56.8%
5	10	3000	1500	50%	3552.16	1776.08	60.2%	64.8%

6	1	3000	1500	5%	3074.09	1537.04	5.1%	5.1%
6	2	3000	1500	10%	3146.43	1573.21	10.4%	10.5%
6	3	3000	1500	15%	3217.14	1608.57	15.9%	16.2%
6	4	3000	1500	20%	3286.34	1643.17	21.6%	22.1%
6	5	3000	1500	25%	3354.10	1677.05	27.4%	28.4%
6	6	3000	1500	30%	3420.53	1710.26	33.5%	35.0%
6	7	3000	1500	35%	3485.69	1742.84	39.9%	41.9%
6	8	3000	1500	40%	3549.65	1774.82	46.4%	49.1%
6	9	3000	1500	45%	3612.48	1806.24	53.2%	56.8%
6	10	3000	1500	50%	3674.23	1837.12	60.2%	64.8%
7	1	3000	1500	5%	3086.61	1543.30	5.1%	5.1%
7	2	3000	1500	10%	3171.52	1585.76	10.4%	10.5%
7	3	3000	1500	15%	3254.83	1627.42	15.9%	16.2%
7	4	3000	1500	20%	3336.65	1668.32	21.6%	22.1%
7	5	3000	1500	25%	3417.06	1708.53	27.4%	28.4%
7	6	3000	1500	30%	3496.14	1748.07	33.5%	35.0%
7	7	3000	1500	35%	3573.96	1786.98	39.9%	41.9%
7	8	3000	1500	40%	3650.59	1825.29	46.4%	49.1%
7	9	3000	1500	45%	3726.08	1863.04	53.2%	56.8%
7	10	3000	1500	50%	3800.50	1900.25	60.2%	64.8%
8	1	3000	1500	5%	3099.18	1549.59	5.1%	5.1%
8	2	3000	1500	10%	3196.81	1598.40	10.4%	10.5%
8	3	3000	1500	15%	3292.96	1646.48	15.9%	16.2%
8	4	3000	1500	20%	3387.73	1693.86	21.6%	22.1%
8	5	3000	1500	25%	3481.19	1740.60	27.4%	28.4%
8	6	3000	1500	30%	3573.42	1786.71	33.5%	35.0%
8	7	3000	1500	35%	3664.46	1832.23	39.9%	41.9%
8	8	3000	1500	40%	3754.39	1877.20	46.4%	49.1%
8	9	3000	1500	45%	3843.26	1921.63	53.2%	56.8%
8	10	3000	1500	50%	3931.11	1965.56	60.2%	64.8%
9	1	3000	1500	5%	3111.81	1555.91	5.1%	5.1%
9	2	3000	1500	10%	3222.30	1611.15	10.4%	10.5%
9	3	3000	1500	15%	3331.54	1665.77	15.9%	16.2%
9	4	3000	1500	20%	3439.59	1719.80	21.6%	22.1%
9	5	3000	1500	25%	3546.53	1773.27	27.4%	28.4%
9	6	3000	1500	30%	3652.40	1826.20	33.5%	35.0%
9	7	3000	1500	35%	3757.26	1878.63	39.9%	41.9%
9	8	3000	1500	40%	3861.16	1930.58	46.4%	49.1%
9	9	3000	1500	45%	3964.12	1982.06	53.2%	56.8%
9	10	3000	1500	50%	4066.21	2033.10	60.2%	64.8%
11	1	3000	1500	5%	3137.22	1568.61	5.1%	5.1%
11	2	3000	1500	10%	3273.89	1636.95	10.4%	10.5%
11	3	3000	1500	15%	3410.05	1705.03	15.9%	16.2%
11	4	3000	1500	20%	3545.72	1772.86	21.6%	22.1%
11	5	3000	1500	25%	3680.91	1840.46	27.4%	28.4%

11	6	3000	1500	30%	3815.66	1907.83	33.5%	35.0%
11	7	3000	1500	35%	3949.97	1974.99	39.9%	41.9%
11	8	3000	1500	40%	4083.87	2041.94	46.4%	49.1%
11	9	3000	1500	45%	4217.37	2108.69	53.2%	56.8%
11	10	3000	1500	50%	4350.49	2175.25	60.2%	64.8%
12	1	3000	1500	5%	3150	1575	5.1%	5.1%
12	2	3000	1500	10%	3300	1650	10.4%	10.5%
12	3	3000	1500	15%	3450	1725	15.9%	16.2%
12	4	3000	1500	20%	3600	1800	21.6%	22.1%
12	5	3000	1500	25%	3750	1875	27.4%	28.4%
12	6	3000	1500	30%	3900	1950	33.5%	35.0%
12	7	3000	1500	35%	4050	2025	39.9%	41.9%
12	8	3000	1500	40%	4200	2100	46.4%	49.1%
12	9	3000	1500	45%	4350	2175	53.2%	56.8%
12	10	3000	1500	50%	4500	2250	60.2%	64.8%

In Table A3 we present the parameters for one subject. Recall that we define the lottery α as a 50:50 mixture of {x, Y} and {X, y}, and the lottery β as a 50:50 mixture of {x, y} and {X, Y}. So α is a 50:50 mixture of bad and good outcomes in time t and t+τ, and good and bad outcomes in the two time periods; and β is a 50:50 mixture of all-bad outcomes and all-good outcomes in the two time periods. In the screen image shown above lottery α is Option A, and lottery β is Option B. These parameters in Table A3 are (1) the decision number, (2) the probability for lottery α, (3) the low amount in kroner, (4) the high amount in kroner, (5) the front end delay in months for the sooner option, and (6) the horizon in months for the later option. The sooner option was for delivery in either 1 month, as shown here for this subject, or in the present. The later option was for delivery in the number of months shown in (6) *after* the front end delay. So for this subject decision #1 would have a later delivery time 9 months beyond the present. If this subject had *not* had a front end delay for the sooner option, the later option for decision #1 would have been 8 months from the present.

Table A3: Parameters for Intertemporal Lottery Choices

Decision	Probability for Lottery α	Low Prize (kroner)	High Prize (kroner)	Front End Delay (months)	Horizon (months)
(1)	(2)	(3)	(4)	(5)	(6)
1	0.1	50	4500	1	8
2	0.2	50	4500	1	8
3	0.3	50	4500	1	8
4	0.4	50	4500	1	8
5	0.5	50	4500	1	8
6	0.6	50	4500	1	8
7	0.7	50	4500	1	8
8	0.8	50	4500	1	8

9	0.9	50	4500	1	8
10	1	50	4500	1	8
11	0.1	50	4500	1	7
12	0.2	50	4500	1	7
13	0.3	50	4500	1	7
14	0.4	50	4500	1	7
15	0.5	50	4500	1	7
16	0.6	50	4500	1	7
17	0.7	50	4500	1	7
18	0.8	50	4500	1	7
19	0.9	50	4500	1	7
20	1	50	4500	1	7
21	0.1	50	4500	1	4
22	0.2	50	4500	1	4
23	0.3	50	4500	1	4
24	0.4	50	4500	1	4
25	0.5	50	4500	1	4
26	0.6	50	4500	1	4
27	0.7	50	4500	1	4
28	0.8	50	4500	1	4
29	0.9	50	4500	1	4
30	1	50	4500	1	4
31	0.1	50	4500	1	1
32	0.2	50	4500	1	1
33	0.3	50	4500	1	1
34	0.4	50	4500	1	1
35	0.5	50	4500	1	1
36	0.6	50	4500	1	1
37	0.7	50	4500	1	1
38	0.8	50	4500	1	1
39	0.9	50	4500	1	1
40	1	50	4500	1	1

Appendix B: Experimental Design and Procedures (WORKING PAPER)

A. The Experimental Design

Subjects are presented with three tasks. The first task identifies individual discount rates, the second task identifies atemporal risk attitudes, and the third task identifies intertemporal risk attitudes. We use tasks with real monetary incentives. Observed choices from all three tasks are then used to jointly estimate structural models of the discounting function defined over utility. The first two tasks are variations on designs that have been well documented in Andersen, Harrison, Lau and Rutström [2008a][2013][2014], so we present the elements briefly. The third task is the new one that is needed for present purposes, and is discussed in the main text.

Individual Discount Rates

Individual discount rates are examined by asking subjects to make a series of choices over two certain outcomes that differ in terms of when they will be received. For example, one option can be 3000 kroner in 1 month, and another option can be 3300 kroner in 13 months. If the subject picks the earlier option we can infer that their discount rate is above 10% for 12 months, starting in 1 month, and if the subject picks the later option we can infer that their discount rate is below 10% for that horizon and start date. By varying the amount of the later option we can identify the discount rate of the individual, conditional on knowing the utility of those amounts to this individual. One can also vary the time horizon to identify the discount rate function, and of course one can vary the front end delay.

We ask subjects to evaluate choices over several time horizons. We consider time horizons between 2 weeks and 1 year. Each subject is presented with choices over four time horizons, and those horizons are drawn at random, without replacement, from a set of thirteen possible horizons (2 weeks, and 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12 months). This design will allow us to obtain a smooth characterization of the discount rate function across the sample for horizons up to one year. We also over-sampled the first three horizons, since this very short-term is clearly of great significance for the alternative specification. Hence each subject was twice as likely to get a horizon of 2 weeks, 1 month or 2 months as any of the later horizons.

Four additional treatments completed the design. First, we varied the time delay to the early payment option on a between-subjects basis: roughly half of the sample had no front end delay, and the other half had a 30-day front end delay. Second, we varied the provision of implied interest rates for each choice on a between-subjects basis, and independently of the front end delay treatment. Third, we varied the order in which the time horizon was presented to the subject: either in ascending order or descending order. Finally, we employ two levels of the principal on a between-subjects basis. These four treatments, the front end delay, information on implied interest rates, the level of the principal, and the order of presentation of the horizon, result in a 2×2×2×2 design. Roughly 1/16 of the sample was assigned at random to any one particular combination.

Risk Attitudes

Risk attitudes were evaluated by asking subjects to make a series of choices over outcomes that involve some uncertainty. Risk attitudes are elicited here simply as a convenient vehicle to estimate the non-linear utility function of the individual. The theoretical requirement, from the definition of the discount factor in (12), is for us to know the utility function over income if we are to correctly infer the discount rate the individual used. The discount rate choices described above are not defined over lotteries.

Our design poses a series of binary lottery choices. For example, lottery A might give the individual a 50-50 chance of receiving 1600 kroner or 2000 kroner to be paid today, and lottery B might have a 50-50 chance of receiving 3850 kroner or 100 kroner today. The subject picks A or B. One series of 10 choices would offer these prize sets with probabilities on the high prize in each lottery starting at 0.1, then increasing by 0.1 until the last choice is between two certain amounts of money. In fact, these illustrative parameters and design was developed by Holt and Laury [2002] to elicit risk attitudes in the United States, and has been widely employed. Their experimental procedures provided a decision sheet with all 10 choices arrayed in an ordered manner on the same sheet; we used the procedures of Hey and Orme [1994], and presented each choice to the subject as a "pie chart" showing prizes and probabilities. We gave subjects 40 choices, in four sets of 10 with the same prizes. The prize sets employed are as follows: [A1: 2000 and 1600; B1: 3850 and 100], [A2: 1125 and 750; B2: 2000 and 250], [A3: 1000 and 875; B3: 2000 and 75] and [A4: 2250 and 1000; B4: 4500 and 50]. The order of these four sets was random for each subject, but within each set the choices were presented in an ordered manner, with increments of the high prize probability of 0.1.

The typical findings from lottery choice experiments of this kind are that individuals are generally averse to risk, and that there is considerable heterogeneity in risk attitudes across subjects: see Harrison and Rutström [2008] for an extensive review. Much of that heterogeneity is correlated with observable characteristics, such as age and education level.

B. The Experiments

Between September 28 and October 22, 2009, we conducted experiments with 413 Danes. The sample was drawn to be representative of the adult population as of January 1, 2009, using sampling procedures that are virtually identical to those documented at length in Andersen, Harrison, Lau and Rutström [2008a]. We received a random sample of the population aged between 18 and 75, inclusive, from the Civil Registration Office and sent out 1969 invitations.[24]

With a sample of 413, on average 25.8 subjects were assigned to each of the 16 treatments for the discounting tasks. We did not develop this experimental design to estimate models at the level of the individual subject or treatment condition, although obviously we will control for these factors.

Our experiments were all conducted in hotel meeting rooms around Denmark, so that travel logistics for the sample would be minimized. Various times of day were also offered to subjects, to facilitate a broad mix of attendance. The largest session had 15 subjects, but most had fewer. The procedures were standard: Appendix B (available online) documents an English translation of the instructions, and shows typical screen displays. Subjects were given written instructions, which were also read out, and then made choices in a trainer task, which was "played out" so that the full set of consequences of each choice were clear. In fact, subjects were paid *Big Ben* caramels instead of money

[24] That recruiting sample was drawn by us from a random sample of 50,000 adult Danes obtained from the Civil Registration Office, which includes information on sex, age, residential location, marital status, and whether the individual is an immigrant. At a very broad level our sample was representative on average: the sample of 50,000 had an average age of 49.8, 50.1% of them were married, and 50.7% were female; our final sample of 413 had an average age of 48.7, 56.5% of them were married, and 48.2% were female.

for all trainers, and the payments were happily consumed when delivered. All interactions were by computer. The order of the block of discount rate tasks and the block of risk attitudes tasks was randomized for each session. After all choices had been made the subject was asked a series of standard socio-demographic questions.

There were 40 discounting choices, 40 atemporal risk attitude choices and 40 intertemporal risk attitude choices, and each subject had a 10% chance of being paid for one choice in each set of 40 choices. Average payments on the first block were 201.4 kroner (although some were for deferred receipt), on the second block the average was 242.5 kroner, and average payments on the third block were 270.7 kroner for a combined average of 714.6 kroner. The exchange rate at the time was close to 5 kroner per U.S. dollar, so earnings averaged approximately 143 dollars per 2 two-hour session for these tasks. Subjects were also paid a fixed show-up fee of 300 kroner or 500 kroner.[25]

For payments to be made in the future, the following language explained the procedures:

> You will receive the money on the date stated in your preferred option. If you receive some money today, then it is paid out at the end of the experiment. If you receive some money to be paid in the future, then it is transferred to your personal bank account on the specified date. In that case you will receive a written confirmation from Copenhagen Business School which guarantees that the money is reserved on an account at Danske Bank. You can send this document to Danske Bank in a prepaid envelope, and the bank will transfer the money to your account on the specified date.

Payments by way of bank transfer are common in Denmark, Copenhagen Business School is a well-known educational institution in Denmark, and Danske Bank is the largest financial enterprise in Denmark as measured by total assets.

Additional References

Harrison, Glenn W., and Rutström, E. Elisabet, "Risk Aversion in the Laboratory," in J.C. Cox and G.W. Harrison (eds.), *Risk Aversion in Experiments* (Bingley, UK: Emerald, Research in Experimental Economics, Volume 12, 2008).

Hey, John D., and Orme, Chris, "Investigating Generalizations of Expected Utility Theory Using Experimental Data," *Econometrica*, 62(6), November 1994, 1291-1326.

Holt, Charles A., and Laury, Susan K., "Risk Aversion and Incentive Effects," *American Economic Review*, 92(5), December 2002, 1644-1655.

[25] An extra show-up fee of 200 kroner was paid to 35 subjects who had received invitations stating 300 kroner, but then received a final reminder that accidentally stated 500 kroner.

Appendix C: Additional Results (WORKING PAPER)

It is a simple matter to extend the econometric model to allow structural parameters to depend on observed demographics and experimental treatments. Table C1 shows the maximum likelihood estimates by including covariates for each of the core structural parameters to reflect observable heterogeneity in responses. We include covariates for individual demographic characteristics as well as task characteristics. Unless otherwise noted, all variables are binary.

Variable FEMALE indicates a female; YOUNG is someone aged less than 40 (so the omitted age category are those aged 40 and over); SINGLE is someone who lives without a spouse or partner; KIDS is someone who has children; OWNER is someone who owns their apartment or house; RETIRED is someone who is retired; STUDENT is someone who is a student; SKILLED is someone with some post-secondary education[26]; LONGEDU is someone who has substantial higher education[27]; INCLOW is someone with household income in 2009 below 300,000 kroner; and INCHIGH is someone with household income in 2009 of 500,000 kroner or more.

Turning to the task treatments, variable RA_FIRST indicates if the risk aversion task was presented before the discounting task; and FEE_HIGH indicates if the higher show-up fee of 500 kroner was used to recruit the subject (rather than 300 kroner); RAHIGH indicates if the two highest prize sets in the atemporal risk aversion tasks were used; FED indicates if a 30-day front end delay was employed for the "sooner" option; IDRORDER indicates if the subject was presented the horizons in increasing order (rather than decreasing order); IDRHIGH indicates if the higher principal of 3000 kroner was used (rather than 1500 kroner); INFO indicates if information on implied interest rates was provided, and IRAHIGH indicates if the two highest prize sets in the intertemporal risk aversion tasks were used.

The results in Table C1 display considerable heterogeneity in the elicited parameters across the subjects in the sample. Implied values of RRA and IES are also reported in Table C2. We find that several of the demographic characteristics are significantly correlated with variations in the core parameters across subjects. Young subjects appear to have lower estimated atemporal risk attitudes (r) than older subjects, with an estimated marginal effect of -0.58 that is statistically significant with a *p*-value of 0.024. We find similar marginal effects for students and subjects with kids, and cannot reject the hypothesis that subjects with these characteristics have linear atemporal utility functions. The results also point to a negative correlation between relative risk aversion and income: subjects with low income are significantly more risk averse than those with middle or high income, and subjects with high income are significantly less risk averse than those with middle income. It is noteworthy that there is *no significant gender effect on atemporal risk aversion*: women exhibit greater risk aversion (+0.14) than men, but the 95% confidence interval on this estimate spans zero, and the *p*-value is only 0.24.

Despite the considerable variation in atemporal risk attitudes, we find that only one of the

[26] Specifically, if the individual has completed vocational education and training or "short-cycle" higher education. Danes commonly refer to the cycle of education in this manner: most short-cycle higher education programs last for less than 2 years; medium-cycle higher education lasts for 3 to 4 years, and includes training for occupations such as a journalist, primary or lower secondary school teacher, nursery and kindergarten teacher, and ordinary nurse; long-cycle higher education typically lasts 5 years and is offered at Denmark's five ordinary universities, at the business schools and various other advanced institutions.

[27] Specifically, the completion of medium-cycle or longer-cycle higher education.

demographic characteristics is significantly correlated with individual discount rates (δ). Young subjects have higher discount rates than older subjects, and the marginal effect of 8.8% is significant with a *p*-value of 0.024. None of the other characteristics have significant marginal effects, although individual discount rates tend to be higher for subjects with kids or students than otherwise. One task characteristic, however, is significantly correlated with discount rates: information on interest rates in the discounting choices has a negative effect in discount rates. The estimated effect is -4.3% with a standard error of 2.3% and a *p*-value of 0.064.

The last panel in Table C1 shows that there is a significant age effect on intertemporal risk attitudes as measured by η. Young subjects are significantly more intertemporal risk averse than those above 40 years of age; the marginal effect is 0.25 with a standard error of 0.09 and a *p*-value of 0.006. We also find a gender effect, with women being more risk averse over lotteries with intertemporal payment profiles than men. The estimated η is 0.25 larger for women, and this estimate has a *p*-value of only 0.006.[28]

The results show that only one task characteristic is significantly correlated with one of the estimated core parameters in the model, which is the treatment on information of interest rates in the discounting choices. The absence of all other treatment effects on the curvature of the atemporal utility function and individual discount rates are noteworthy, since several of these treatments have been found to have significant effects on behavior in similar types of studies. In particular, we do not find a significant effect from varying the stakes in the atemporal risk aversion task or in the discount rate task, and individual discount rates do not vary significantly with the delay to the sooner payment option.

Table C2 shows the implied ML estimates of relative risk aversion and the intertemporal elasticity of substitution. Younger subjects, students, and those with kids have linear atemporal utility functions and the IES coefficient is effectively infinite for these subjects. We also infer significantly negative marginal effects on the RRA coefficient for these three types of subjects. The marginal effect on RRA for young subjects is -0.46 with a *p*-value of 0.079, it is -0.52 for subjects with kids (*p*-value of 0.066), and is -0.58 for students (*p*-value of 0.063). Finally, the results point to a significant positive marginal effect on RRA for subjects with low income and a significant negative marginal effect for subjects with high income. Hence, there is evidence that RRA declines with income, but we find no significant effect of income on the IES coefficient.

We can also evaluate the total effects of several of the demographic characteristics on the estimated RRA and IES, by estimating marginal effects without controls for other characteristics. We calculate total effects since many demographic characteristics co-vary in the population and therefore also in our sample. For example, the men in our sample have a number of characteristics that differ from the women apart from sex. By not controlling for these other characteristics of men, we can estimate the difference in RRA and IES between men and women that jointly reflects all of these differences. To consider the total effects, we simply repeat the statistical analysis shown in Table C1 and C2 but with only one demographic characteristic included at a time. In this manner our estimates include all of the demographic characteristics correlated with the characteristic of interest.

[28] We find a significant effect of sex on relative risk aversion and discount rates when the intertemporal utility function is additively separable: women appear to be significantly more risk averse and patient in monetary terms than men.

The maximum likelihood estimates of RRA and IES for a selection of demographic characteristics are displayed in Table C3. We find that women are more risk averse than men with an estimated RRA of 0.45 for women and 0.33 for men. This difference in RRA between men and women is statistically significant with a *p*-value of 0.026. However, we can not reject the hypothesis that men and women have identical IES coefficients; the difference of 0.37 has a *p*-value of 0.740. There is an age effect on the two RRA and IES coefficients. The older age group has a higher RRA and lower IES than younger subjects, where the difference in RRA is significant with a *p*-value of 0.064 and the difference in IES has a *p*-value of 0.102. We do not find any significant variation in the estimated RRA and IES coefficients for the other individual characteristics that are included in Table C3. Hence we can not reject the hypothesis that the coefficients of RRA and IES are similar across income groups and education levels.

Table C1: Maximum Likelihood Estimates with Covariates

N=49,560 observations, based on 413 subjects

Parameter	Point Estimate	Standard Error	*p*-value	95% Confidence Interval	
			Atemporal Utility Function (r)		
Constant	0.58	0.257	0.024	0.08	1.08
RAfirst	-0.09	0.151	0.537	-0.39	0.20
FEEhigh	0.04	0.094	0.694	-0.15	0.22
RAhigh	-0.03	0.087	0.762	-0.20	0.14
Female	0.14	0.120	0.241	-0.09	0.38
Young	-0.58	0.257	0.024	-1.08	-0.08
Single	-0.21	0.250	0.409	-0.70	0.28
Kids	-0.58	0.257	0.024	-1.08	-0.08
Owner	0.04	0.162	0.791	-0.27	0.36
Retired	-0.17	0.184	0.362	-0.53	0.19
Student	-0.56	0.264	0.034	-1.08	-0.04
Skilled	-0.18	0.134	0.171	-0.45	0.08
Longedu	0.07	0.131	0.572	-0.18	0.33
IncLow	0.29	0.152	0.052	0.00	0.59
IncHigh	-0.37	0.191	0.050	-0.75	0.00
μ^{RA}	0.18	0.011	<0.001	0.15	0.20
			Discounting Function (δ)		
Constant	0.113	0.055	0.039	0.006	0.221
RAfirst	0.032	0.033	0.332	-0.033	0.097
FEEhigh	0.001	0.025	0.968	-0.048	0.050
FED	0.020	0.025	0.429	-0.030	0.070
IDRorder	-0.038	0.025	0.137	-0.087	0.012
IDRhigh	0.024	0.029	0.398	-0.032	0.081
INFO	-0.043	0.023	0.064	-0.088	0.003
Female	-0.016	0.025	0.512	-0.065	0.032
Young	0.088	0.039	0.023	0.012	0.164
Single	0.014	0.063	0.826	-0.108	0.137
Kids	0.080	0.054	0.140	-0.026	0.186
Owner	-0.039	0.034	0.249	-0.104	0.027
Retired	0.015	0.064	0.812	-0.111	0.141
Student	0.136	0.084	0.106	-0.029	0.301
Skilled	0.019	0.036	0.597	-0.052	0.090
Longedu	-0.014	0.033	0.657	-0.078	0.049
IncLow	-0.043	0.040	0.279	-0.120	0.035
IncHigh	0.045	0.038	0.238	-0.030	0.119
μ^{DR}	0.16	0.012	<0.001	0.14	0.18

Intertemporal Utility Function (η)

Constant	0.09	0.208	0.652	-0.31	0.50
RAfirst	0.06	0.090	0.527	-0.12	0.23
FEEhigh	0.07	0.091	0.475	-0.11	0.24
FED	-0.04	0.085	0.664	-0.20	0.13
IDRorder	-0.10	0.083	0.238	-0.26	0.06
IRAhigh	0.05	0.095	0.606	-0.14	0.23
Female	0.25	0.090	0.006	0.07	0.42
Young	0.19	0.102	0.068	-0.01	0.39
Single	-0.08	0.157	0.632	-0.38	0.23
Kids	0.07	0.101	0.517	-0.13	0.26
Owner	-0.01	0.121	0.966	-0.24	0.23
Retired	-0.28	0.200	0.160	-0.67	0.11
Student	-0.10	0.197	0.605	-0.49	0.28
Skilled	0.05	0.132	0.685	-0.21	0.31
Longedu	0.04	0.135	0.776	-0.23	0.30
IncLow	0.09	0.221	0.676	-0.34	0.53
IncHigh	0.09	0.104	0.382	-0.11	0.30
μ^{SDR}	0.18	0.010	<0.001	0.16	0.20

Table C2: Implied Maximum Likelihood Estimates

N=49,560 observations, based on 413 subjects

Parameter	Point Estimate	Standard Error	*p*-value	95% Confidence Interval	
			Relative Risk Aversion		
Constant	0.60	0.232	0.010	0.15	1.06
RAfirst	-0.07	0.138	0.591	-0.35	0.20
FEEhigh	0.05	0.085	0.576	-0.12	0.22
RAhigh	-0.03	0.083	0.761	-0.19	0.14
FED	-0.01	0.019	0.678	-0.04	0.03
IDRorder	-0.02	0.020	0.307	-0.06	0.02
IRAhigh	0.01	0.020	0.602	-0.03	0.05
Female	0.17	0.112	0.130	-0.05	0.39
Young	-0.46	0.262	0.079	-0.97	0.05
Single	-0.22	0.227	0.333	-0.67	0.23
Kids	-0.52	0.284	0.066	-1.08	0.03
Owner	0.04	0.147	0.787	-0.25	0.33
Retired	-0.24	0.163	0.138	-0.56	0.08
Student	-0.58	0.314	0.063	-1.20	0.03
Skilled	-0.16	0.125	0.202	-0.40	0.09
Longedu	0.08	0.118	0.515	-0.15	0.31
IncLow	0.29	0.138	0.037	0.02	0.56
IncHigh	-0.32	0.188	0.089	-0.69	0.05
			Intertemporal Elasticity of Substitution		
Constant	1.72	0.760	0.024	-0.23	3.21
RAfirst	0.33	0.568	0.563	-0.78	1.44
FEEhigh	-0.10	0.283	0.715	-0.66	0.45
RAhigh	0.08	0.266	0.759	-0.44	0.60
Female	-0.34	0.428	0.432	-1.17	0.50
Young	.	.	.	.	.
Single	0.95	1.787	0.596	-2.56	4.45
Kids	.	.	.	.	.
Owner	-0.12	0.491	0.810	-1.08	0.84
Retired	0.70	0.956	0.466	-1.18	2.57
Student	.	.	.	.	.
Skilled	0.79	0.979	0.417	-1.12	2.71
Longedu	-0.19	0.426	0.649	-1.03	0.64
IncLow	-0.58	0.599	0.333	-1.75	0.59
IncHigh	3.10	2.675	0.247	-2.15	8.34

Table C3: Maximum Likelihood Estimates of Total Effects

N=49,560 observations, based on 413 subjects

Variable	Estimate	Standard Error	*p*-value	95% Confidence Interval	
			Relative Risk Aversion		
Female	0.45	0.062	<0.001	0.32	0.57
Male	0.33	0.060	<0.001	0.21	0.45
Young	0.33	0.048	<0.001	0.24	0.43
Old	0.42	0.066	<0.001	0.29	0.55
Unskilled	0.38	0.065	<0.001	0.25	0.51
Skilled	0.35	0.072	<0.001	0.21	0.50
Longedu	0.41	0.064	<0.001	0.28	0.53
IncLow	0.42	0.076	<0.001	0.27	0.57
IncMiddle	0.45	0.077	<0.001	0.30	0.60
IncHigh	0.36	0.055	<0.001	0.24	0.45
			Intertemporal Elasticity of Substitution		
Female	3.86	1.193	<0.001	1.53	6.20
Male	4.23	0.903	<0.001	2.46	6.00
Young	7.98	3.200	0.013	1.71	14.25
Old	3.30	0.699	<0.001	1.93	4.67
Unskilled	4.16	1.026	<0.001	2.15	6.17
Skilled	4.80	2.018	0.017	0.84	8.75
Longedu	3.69	1.009	<0.001	1.71	5.67
IncLow	3.54	1.152	0.002	1.28	5.80
IncMiddle	2.80	0.747	<0.001	1.33	7.26
IncHigh	5.21	1.388	<0.001	2.49	7.93